A FLORISTIC STUDY OF THE LEPIOTACEOUS FUNGI OF KERALA AND SOME TAXONOMIC OBSERVATIONS ON THE GROUP

Thesis submitted to the University of Calicut
in partial fulfilment of the requirements for the Degree of
DOCTOR OF PHILOSOPHY
in Botany

By

ARUN KUMAR T. K.

UNIVERSITY OF CALICUT
DEPARTMENT OF BOTANY
KERALA-673 635, INDIA

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Indeed, the present status of the science of Mycology is a summation of our appreciation of their (fungal) beauty, variety and diversity, a reflection of our curiosity and efforts to probe into them to get at the truth about them, our predicament in trying to combat the damage they do, and our hopes of harnessing their power to advantage.

Beauty, Goodness and Truth thus form the basic and perennial theme of mycology and the philosophy of the mycologist.

- Prof. C. V. Subramanian

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DEPARTMENT OF POST-GRADUATE STUDIES AND RESEARCH IN BOTANY
KERALA - 673 635, INDIA

Dr. P. MANIMOHAN
Reader

4-9-2007

CERTIFICATE

This is to certify that this thesis, entitled '**A floristic study of the lepiotaceous fungi of Kerala and some taxonomic observations on the group**', submitted to the University of Calicut by Arun Kumar T. K. for the award of Ph. D. Degree in Botany, is a record of bonafide research work carried out by him under my supervision and guidance and that no part of this thesis has formed the basis for the award of any degree, diploma or other similar title or recognition.

Dr. P. MANIMOHAN

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DECLARATION

I hereby declare that this thesis, entitled '**A floristic study of the lepiotaceous fungi of Kerala and some taxonomic observations on the group**', is a record of bonafide research work carried out by me and that no part of this thesis has been presented earlier for the award of any degree, diploma or similar title of this or any other University.

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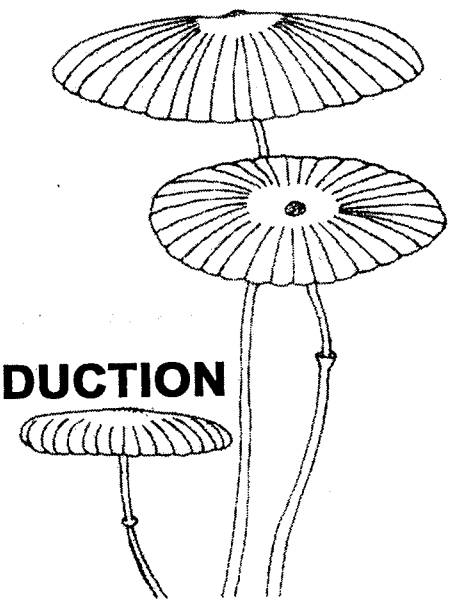
Chapter 1



INTRODUCTION

Chapter 1
INTRODUCTION

The oft-quoted estimate of a 1.5 million fungal species (Hawksworth 1991, 2001) inhabiting our planet, fervently motivates both a fungal taxonomist and an application-oriented biotechnologist alike. The magnitude of fungal diversity should inspire not only mycologists but also any one concerned with issues of food security, waste utilization and recycling, public health, and maintenance of biodiversity itself. The importance of prospecting fungal wealth for yielding great sustainable benefits to the present as well as future generations has been recognized and well-stressed (Subramanian 1982, 1992; Hawksworth 1993; Hawksworth & Rossman 1997). This is especially relevant and encouraging for third world tropical countries like India that are fortunate to be still left with a considerable part of the world's floristic wealth, promising economic progress through biotechnology.

However, in India, bioinventorying and bioprospecting exist in a dismally inadequate state amidst the alarmingly high rate of habitat destruction. Systematic cataloguing of Indian mycoflora has received only scant attention. The larger fungi are a particularly neglected group except for the efforts of a few dedicated mycologists in the Himalayan foot hills and peninsular India. Considering a documented vascular plant flora of more than 15000 species, India's mycoflora must be very rich and diverse.

The Western Ghats region of peninsular India is recognized as one of the existing mega diversity hotspots of the world that poses an important challenge in inventorying and monitoring of biological diversity. The State of Kerala, which includes a major part of the Western Ghats, is a floristically rich region that is especially rich in agarics. Documentary works on agarics of Kerala have gradually gained momentum of late by the concerted efforts of a few mycologists. Much more intense alpha taxonomic studies focusing on individual agaric families and genera are vital for the preparation of an agaric flora of Kerala. As Korf (2005) noted, without monographic and inventory studies concentrating on fungal groups, 'no progress in taxonomy (nor also in phylogenetic biology) can ever occur' and hence a divide-and-study approach seems highly desirable and much more practical in better understanding a region's biodiversity.

The documentation of a group of white-spored agarics belonging to the family *Agaricaceae*, known as the lepiotaceous fungi, of Kerala has been scant. Their role as efficient agents of nutrient retention and recycling in tropical, subtropical and temperate regions has been well-recognized (Guzmán & Guzmán-Dávalos 1992; Johnson 1999). A few lepiotaceous fungi are edible and many are rich with chemical compounds that are potentially bioactive (Didukh *et al.* 2003). Only 20 species of lepiotaceous agarics have been known from the State so far, thanks to a few scattered reports by Sathe & Sasangan (1977), Sathe & Daniel (1980), Leelavathy *et*

al. (1981), Manimohan *et al.* (1988), Vrinda et al. (1997,1999, 2001, 2003) and Kumar & Manimohan (2004).

The lepiotaceous fungi are a relatively well-studied group of agarics known from around the world. However, lots of taxonomic confusions still exist in this group partly because of a lack of adequate knowledge on its tropical representatives that are expected to be much more diverse and with new character combinations. Florida is an example of a region where floristic studies on lepiotaceous fungi have been considerably accomplished with the documentation of about 70 species by various workers (Akers *et al.* 2000). Guzman & Guzman-Davalos (1992) reported 59 species from Mexico. These studies revealed a large number of new taxa and highlighted the need for similar floristic explorations in other parts of the world where the lepiotaceous fungi remain relatively unknown. Such a situation forms the basic impetus for this study.

This treatise is a preliminary floristic study of the lepiotaceous fungi as they occur in Kerala. A first-round investigation of the characters of cheilocystidia and pileal covering structures of three representative lepiotaceous taxa at the subcellular level to assess their potential to be developed as useful taxonomic markers in lepiotaceous fungi is also attempted.

A detailed review of the literature on taxonomy, biology and distribution of the lepiotaceous fungi is given in chapter 2. Introductory information on the physiography, vegetation and climate of Kerala along with

a distributional map and photographs of some of the main collection sites is given in chapter 3. The materials employed during this study, procedures followed while collecting and describing taxa, ultrastructural protocols adopted, equipments and chemicals used, major works consulted and the taxonomic principles followed are given in detail in chapter 4. Keys to all the lepiotaceous taxa encountered during this study along with detailed descriptions and illustrations of each taxon is provided as a systematic account in chapter 5. General observations on the results of the floristic study and the results and discussion on the ancillary ultrastructural studies are given in chapter 6. A brief summary of the whole work is provided in chapter 7 and all the literature cited are listed in the 'References' section. Recipes of all stains, reagents and buffers used are given as an appendix. An index to all the fungal species names mentioned in this treatise is given at the end.

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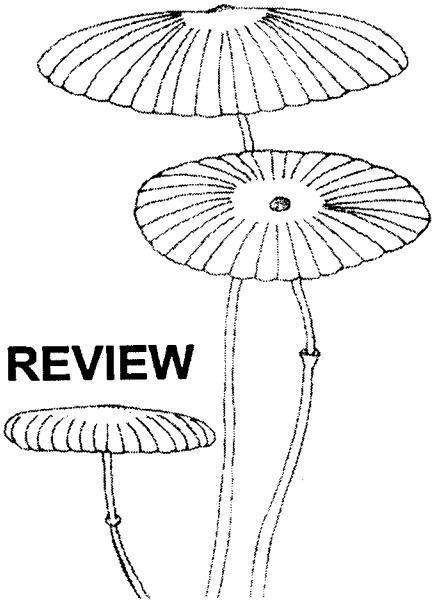
Chapter 2



LEPIOTACEOUS FUNGI - A REVIEW

Chapter- 2
LEPIOTACEOUS FUNGI - A REVIEW

2.1 Introduction

The genus *Lepiota* (Persoon) S. F. Gray and its satellite genera such as *Chlorophyllum* Massee, *Cystolepiota* Singer, *Leucoagaricus* (Locquin) Singer, *Leucocoprinus* Patouillard and *Macrolepiota* Singer, comprising the pale-spored members of the family *Agaricaceae* Chevallier, are often collectively referred to by mycologists as the 'lepiotaceous fungi'. Pluteoid basidiocarps with free lamellae, light-coloured spores, presence of an annulus, and the general absence of a volva are the common characters of this assemblage of exclusive saprobes. Due to their relative dominant presence in any macromycete flora, this group has enjoyed special attention from mycologists. There are approximately 900 species of lepiotaceous fungi (Kirk *et al.* 2001) known from around the globe.

Taxonomic concepts

Although members of this large and highly diverse group are easily recognized in the field by their characteristic macroscopic features, because of the very few delimiting characters used and often due to the seamless character variations observed, generic, infrageneric and infraspecific delimitations have always been contentious. Many earlier workers like Morgan (1906, 1907), Murrill (1911, 1912, 1914, 1949), Ricken (1914), Lange (1915), Rea (1922), Kauffman (1924), Kühner (1936), Locquin

(1945b), Kühner & Romagnesi (1953), Smith (1954, 1965) and authors like Atkinson (1961) and Arora (1986) used a system that clubbed together the diverse lepiotoid taxa (i.e., members of the present day, *Cystolepiota, Leucoagaricus, Leucocoprinus*, *Lepiota* and *Macrolepiota*) inside a single genus - the *Lepiota sensu lato*. Kühner's (1936) concept of Lepiotaceous fungi consisted of the genus *Lepiota* subdivided into 14 sections mainly based on the structure of pileal covering, and the genus *Limacella* Earle. Locquin (1945b) classified the group into three distinct genera: *Lepiota*, *Leucocoprinus* and *Cystoderma* Fayod. He further divided *Lepiota* into eight and *Leucocoprinus* into four subgenera.

Later, Singer (1986) introduced a much more refined and restricted generic concept where he split the single large group into three tribes, *Lepioteae* Fayod, *Leucocoprineae* Patouillard and *Cystodermatae* Singer, which together accommodated 20 smaller and segregate genera of *Agaricaceae*, other than those belonging to the tribe *Agariceae* Patouillard. As conceptualized by Singer, the tribe *Lepioteae* is characterized by species having spores without a germ-pore (or rarely with an extremely indistinct one) and without a metachromatic endosporium in cresyl blue mounts. The tribe *Leucocoprineae* is characterized by species bearing spores with a smooth or slightly ornamented complex wall turning distinctly metachromatic in cresyl blue and with a broad or sometimes a very narrow germ-pore, and mostly possessing a movable annulus. The tribe *Cystodermatae* included species with inamyloid, amyloid or rarely dextrinoid spores without a germ-

pore, white to ochraceous spore-print, adnexed to adnate or rarely decurrent lamellae, and context hyphae with clamp-connections. Bas (1988, 1990) considered the tribe *Cystodermatae* of Singer as belonging to the family *Tricholomataceae* R. Heim ex Pouzar, an argument which was later found supported by molecular investigations (Johnson & Vilgalys 1998, Moncalvo *et al.* 2002, Vellinga 2004a). If such a transfer is agreed upon, the lepiotaceous members presently confine to the two tribes, *Lepioteae* and *Leucocoprineae*.

The status of a distinct family for this heterogenous group, the *Lepiotaceae* Roze, has been given by workers like Kühner & Romagnesi (1953), Smith (1954), Sundberg (1971a, 1971b, 1976), Smith & Sundberg (1979), Contu (1991), and Bon (1996). The family *Lepiotaceae* of Kühner & Romagnesi (1953) included the brown-spored *Psalliota* Fries, along with other white-spored lepiotaceous genera. Bon (1996) segregated the family *Lepiotaceae* from *Agaricaceae* as a group with pale spore-print colour, and recognized two tribes, *Lepioteae* and *Leucocoprinae*, within that family. Bon's *Lepioteae* included six lesser known genera and the genus *Lepiota*, all with non-metachromatic spores in cresyl blue, and *Leucocoprineae*, which housed five genera with members having spores that showed metachromatism. The genera were further classified into subgenera, sections and subsections. Interestingly, the genus *Melanophyllum* Velen with coloured spores, that Singer (1986) kept under the tribe *Agariceae* and

which Pegler (1986) incorporated in *Cystodermatae* was also placed in *Lepioteae* (Bon 1996).

Thus the concepts of supraspecific lepiotaceous taxa differed more or less with each individual taxonomist. However, historically, the concepts proposed by Kühner (1936), Locquin (1945b), Singer (1986) and Bon (1996) were the generally accepted ones. Of these, Singer's concept is remarkable in being the only one based on a study of both tropical and temperate taxa. Apart from Singer (1986) and Bon (1996), Pegler (1977, 1983, 1986), Candusso & Lanzoni (1990) and Vellinga (2001g) are the other major contributors who followed narrow generic concepts in the group. The major classification systems suggested for the group are outlined in table 1.

Phylogeny

Drawing conclusions from the available macroscopic, microscopic, biochemical and ecological characteristics, Bon (1996) speculated a possible evolutionary history of the extant lepiotaceous taxa. He believed the genus *Pseudobaeospora* Singer (*Marasmiaceae*) to be the ancestor of the lepiotaceous fungi and *Lepiota* subsection *Parvannulatae* Bon to be the most primitive lepiotaceous group. Further, according to him, lineages derived from *Parvannulatae* lead to the evolution of the present day taxa considered under the two tribes *Lepioteae* and *Leucocoprineae*. The genus *Leucocoprinus* was envisaged to have evolved from the *Leucoagaricus* lineage with *Sericeomyces* Heinemann as the latter's most probable

immediate ancestor. According to Bon, the basal lineage of *Chlorophyllum* and *Macrolepiota* seemed uncertain.

Subsequently, attempts were made by Johnson & Vilagalys (1998) to elucidate the phylogenetic relationships of *Lepiota sensu lato* using nuclear large subunit (nLSU) ribosomal DNA (rDNA) sequences. Evidences from their study supported the tribal level placements within the family *Agaricaceae* as expounded by Singer (1986). Based on additional combined morphological and molecular phylogenetic analyses, Johnson (1999) further concluded that Singer's phenetic classification within *Lepiota sensu lato* could be endorsed after transferring a section (*Echinatae* Fayod) of *Lepiota sensu stricto* to *Cystolepiota*, as proposed by Knudsen (1978, 1980). The study also found *Leucoagaricus* to be paraphyletic and that *Chlorophyllum* could be retained as a genus distinct from the morphologically similar *Macrolepiota*.

Recently, Vellinga (2003a, 2003b, 2004a), based on her investigations with nuclear ribosomal Internal Transcribed Spacer (ITS) and nLSU markers, provided additional information on the evolutionary affinities of and within the group. According to Vellinga (2004a), the tribes of Singer were not supported by molecular phylogenetic analysis; differentiation into tribes on the basis of spore-wall reaction with cresyl blue and iodine solutions appeared unreliable and spore-colour seemed to be a less important character; *Leucoagaricus* and *Leucocoprinus* along with *Sericeomyces* formed one monophyletic clade and combined dataset

analyses indicated the placement of *Lepiota*, *Cystolepiota*, *Melanophyllum*, *Macrolepiota*, and *Coprinus comatus* Fries and allies within the tribe *Lepioteae*. The phylogenetic position of *Melanophyllum* as revealed by her study upheld Bon's (1996) view.

The molecule-based studies unveiled a general phylogenetic sketch of the lepiotaceous fungi. Overall, a placement inside the *Agaricaceae* seemed justifiable and the creation of a separate family (*Lepiotaceae*) was found to be unwarranted (Vellinga 2004a). The necessity for integrating more morphological data, especially on the covering layers (veil) was recognized (Vellinga 2003a, 2004a). However, uncertainties regarding strict taxonomic demarcations within the group persist. Low resolution of nLSU and ITS data and poor bootstrap supports for many clades in these studies made the development of a new phylogenetic concept difficult (Vellinga 2004a). Also, conspicuous was the absence of adequate tropical representatives in these analyses of a group with greater species diversity in the tropics. Certain lesser studied allied genera having unique character combinations and a limited distribution, like *Clarkeinda* O. Kuntze, *Hiatulopsis* Singer & Grinling, and *Janauaria* Singer have not yet been treated in any of these molecular investigations.

2.2 Taxonomic characters

A very high level of character variation exists among the known taxa as evident from the treatises like those of Singer (1986), Candusso & Lanzoni (1990), Bon (1996), and Vellinga (2001g), and from several other

scattered descriptions and illustrations of lepiotaceous fungi from around the world. This presently known range of variation of characters is based mainly on observations on temperate species that are better studied than their much diverse tropical representatives. The actual range of variation must be much higher than what we already know.

2.2.1 General appearance of basidiomata

Lepiotaceous agarics produce pluteoid basidiomata which may be small, medium-sized, or large, and are noted for their attractively coloured scales scattered all over the surface. Basidiomata may be thick and fleshy (as in *Chlorophyllum*, *Clarkeinda*, *Macrolepiota*, and many species of *Leucoagaricus*), or slender (many *Leucocoprinus* species) or something in between (most *Lepiota* species). Rarely the basidiomata are extremely fragile (e.g. *Leucocoprinus fragilissimus* (Berkeley & Curtis) Patouillard). The basidiomata are mostly solitary, but they may be found scattered, in small isolated groups, or even in dense clusters (e.g. species of the '*Leucocoprinus badhami* complex'). The surface and context of many taxa exhibit colour change on touch, when bruised, on drying, with age, or on exposure to chemicals like ammonia.

2.2.2 Pileus

Pileal size ranges from a few millimeters to several centimeters (up to 25 cm) in diameter. Pilei are globose to subglobose when very young and gradually become campanulate to convex and finally broadly convex to

applanate with maturity. Pileal margin may be entire, eroded, serrate, or appendiculate; it exceeds lamellae in many species and in some cases becomes upturned with age. Many species, especially those of the genus *Leucocoprinus* have striations on the pileal surface that extend from the centre towards the margin and these striations may be fine or distinctly plicate/sulcate. A distinctly striate pileus helps in preliminary differentiation of the genera *Leucoagaricus* and *Leucocoprinus*. An umbo may or may not be present at the disc. The umbo may be indistinct (as in *Lepiota citrophylla* (Berkeley & Broome) Saccardo and *Leucocoprinus cretaceus* (Bulliard) Locquin) or may be distinct as in the case of species like *Macrolepiota dolichaula* (Berkeley & Broome) Pegler & Rayner.

Nature of the pileal surface is remarkably diverse in this group. The high variation in the structure of pileal covering is attributed to the amount and texture of tissue originally derived from the blematogen-type universal veil (Kauffman 1924). Such a wide character variation that could be easily appreciated macroscopically is taxonomically valuable. Pileal surface may be silky-smooth, granulose, wooly-floccose, or with scattered, minute or large fibrillose or membranous scales covering the pileus. These detersile or innate scales may be appressed, recurved, erect or perfectly conical/pyramidal and are mostly concentrated towards the disc and sparser towards the margin. In many cases the entire disc may appear pruinose to smooth. In the genus *Clarkeinda*, a thick and large cartilaginous layer is found covering the pileal disc. The scales may be concolorous or may be

differently and contrastingly coloured than the background surface. Colour of scales and background range from pure white to different shades of yellow, orange, brown, reddish brown, purple, green, grey or dark grey and is a major character employed for species-level identifications. Although highly useful for preliminary determinations, this character is not solely dependable as different species with similar colour patterns are frequently encountered. Two distinct species, *Lepiota xanthophylla* Orton and *L. elaiophylla* Vellinga & Huijser were considered under a single name because of similarity in colour until Vellinga & Huijser (1997) recognized their distinctiveness. Moreover, colour variants of the same species are also rarely found. For example, a white variety of *L. micropholis* (Berkeley & Broome) Saccardo is known and is recognized as a variety '*lactea*'. Colour variants of *Macrolepiota rachodes* (Vittadini) Singer are known (Candusso & Lanzoni 1990) and have been photographically well-documented by Britenbach & Kranzlin (1995).

2.2.3 Stipe

Length of stipe ranges from about 1 cm to about 25 cm and thickness ranges from less than one millimeter to about 20 mm. Although the ratio of stipe length to pileal diameter seems to be an inconsistent character for the group, the case of *Macrolepiota dolichaula* is an exception where the stipe length has always been noted to be twice its pileal diameter (Pegler 1986). Generally, the stipe is cylindrical with a slightly bulbous base and is centrally attached. In many leucocoprinoid members, it is somewhat narrower at the

apex but gradually expands towards the base and becomes distinctly swollen or bulbous at the base. In species like *Chlorophyllum abruptibulbum* (Heim) Vellinga, an abruptly bulbous base is observed. The stipe may be initially solid or fistulose but may gradually become hollow with age.

The surface of stipe may be smooth to pruinose or floccose (as in *Cystolepiota*, *Leucocoprinus cretaceus*) or in most cases fibrillose. Also, the surface may be covered by minute to large scales similar to those covering the pileus. Such distinct scalar covering is predominantly noticed in species of the genus *Lepiota*. The scales are always absent above the annulus. The stipe surface and scales may be concolorous with that of the pileus or may vary.

Base of the stipe may arise from a basal mycelium or from mycelial cords. Species of *Lepiota*, *Leucoagaricus*, *Leucocoprinus* and *Macrolepiota* have stipe bases with mycelial cords. *Lepiota subincarnata* Lange and *Leucocoprinus lacrymans* T. K. A. Kumar & Manimohan are examples of species arising from thick white mycelial cords. Agerer & Iosifidou (2004) used the name 'rhizomorph' for such mycelial cords and demonstrated their importance in testing phylogenetic hypotheses, including those of lepiotaceous agarics.

2.2.4 Annulus and Volva

All lepiotaceous genera are characterized by an annulus. Kühner (1936) gave information with detailed illustrations on the different types of

annulus found in *Lepiota sensu lato*. A membranous annulus is considered as a constant trait of members of the tribe *Leucocoprineae* (*Leucoagaricus*, *Leucocoprinus*, *Macrolepiota*, *Chlorophyllum*, *Clarkeinda*), and members of the tribe *Lepioteae* (*Lepiota*, *Cystolepiota*) are characterized by two main types of annulus, one of a crumbly-powdery nature and the other fibrillose (Akers 2005). As distinct from other leucocoprinoid genera, many members of *Chlorophyllum* and *Macrolepiota* have a movable, double-edged (bilipped) annulus which according to Bon (1996) is taxonomically significant. Many membranous annulii like those found in *Leucoagaricus rubrotinctus* (Peck) Singer have a well-defined and visibly thickened margin with contrastingly coloured squamules. Many species belonging to *Lepiota* (e.g. *L. erythrosticta* Berkeley & Broome (Saccardo)) possess an ill-defined annulus found as a broken fibrillose ring. In a majority of cases, the annulus is superiorly positioned on the stipe, but central to inferior placement are also common. Both persistent as well as evanescent annuli are recorded.

A volva is generally absent in lepiotaceous fungi, but is observed in a few genera like *Clarkeinda* and *Volvolepiota* Singer. The extremely thin membranous saccate volva in *Clarkeinda* may not be detected if the stipe base is not properly dug out of the substratum. Volvate species of *Leucoagaricus* (*L. bivelatus*, Akers & Ovrebo 2005) have also been reported.

2.2.5 Lamellae

The lamellae may be less than one millimeter to about 12 mm wide and are always freely attached. They are mostly ventricose in shape.

Spacing varies with species and it may be very crowded as in *Lepiota calcicola* Knudsen, crowded as in many species like *L. perplexa* Knudsen, *L. subincarnata*, and *Leucocoprinus meleagris* (Sowerby) Locquin or close in species such as *Leucocoprinus fragilissimus*. The lamellae are mostly light-coloured (shades of white, yellow, cream, pale green). In *Chlorophyllum molybdites* (Meyer) Massee and in the genus *Clarkeinda*, the lamellae are greyish to green. Members of the genus *Melanophyllum* have red to purplish pink or even blue-green colours (e. g., *Melanophyllum eyrei* (Massee) Singer). The lamella-edge may be finely fimbriate to denticulate. In species like *Leucocoprinus lacrymans*, the edge appears brown with coloured cheilocystidia.

2.2.6 Basidiospores

Characters of basidiospores serve as extremely important criteria in lepiotaceous taxonomy. Spore-prints of lepiotaceous fungi are white or pale coloured. The exceptions are *Chlorophyllum molybdites* and *Clarkeinda* that have greenish spore-prints. Although a pale spore-print is generally considered characteristic of the group, Vellinga (2004a) on the basis of molecular studies provide contradictory evidences. In lepiotaceous fungi, spore-sizes vary widely. The smallest spores in the group are found in *Cystolepiota* and in members of *Lepiota* section *Echinatae*. Spores of the smallest dimension (3.5 × 2 µm) are present in species like *Lepiota jacobi* Vellinga & Knudsen. Large spores are found in many *Lepiota* species (e.g.

Lepiota magnispora Murrill where spore lengths extend up to 25 µm) and in many species of *Macrolepiota* and *Leucoagaricus*.

A variety of spore-shapes are observed in this group and these are important in infrageneric classification of *Lepiota*. The common spore-shapes found in the lepiotaceous members are ellipsoid, broadly ellipsoid, ovoid, amygdaliform, fusiform and spurred. In lepiotaceous agarics, spurred and fusiform spores are present only in species of the genus *Lepiota*. In species like *Chlorophyllum molybdites* and many other taxa, the spore-apex is truncate. Spore-wall may be thin as noted in many *Cystolepiota* spores or may be slightly thick to thick (up to 2 µm) as in other genera. Spores of the leucocoprinoid type mostly have a complex wall structure consisting of different layers. Clémençon (2004) gives an elaborate discussion on spore-wall architecture of the group.

Spore-wall is typically smooth in lepiotaceous fungi although exceptions are found with slight ornamentation on the spores of some species like *Cystolepiota pulverulenta* (Huijsman) Vellinga (Vellinga 2001f). Scanning electron microscopic studies conducted by Pegler & Young (1971) had revealed the occurrence of wall ornamentation in *Melanophyllum*, *Leucoagaricus* and possibly in *Macrolepiota rachodes*. Spores with a verrucose surface are reported using light microscopic studies in *Melanophyllum eyrei* (Bon 1996; Vellinga 2001f). Spore wall is invariably smooth in species of *Lepiota*, *Chlorophyllum*, *Clarkeinda* and *Leucocoprinus*.

A visible germ-pore is characteristic of the tribe *Leucocoprineae*, but it is entirely absent in genera like *Lepiota*, *Cystolepiota* and *Melanophyllum*. Depending on the species, these germ-pores may be wide (up to 2 µm) or inconspicuous. The development of germ-pore in the basidiospores has been used (Heinemann 1969) as a delimiting feature to separate *Leucoagaricus* from *Macrolepiota*. The germ-pore in many *Leucoagaricus* (e. g. *L. leucothites* (Vittadini) Wasser, *L. macrorhizus* Locquin ex Horak) and *Leucocoprinus* species (e. g. *Leucocoprinus birnbaumii* (Corda) Singer, *L. brebissoni* (Godey) Locquin, *L. badhamii* (Berkeley & Broome) Locquin) contains a conspicuous plug which gets stained with cresyl blue and toluidine blue. This plug remains unstained in *Macrolepiota procera* (Scopoli) Singer, *M. excoriata* (Schaeffer) Wasser and *M. rachodes* (Clémençon 2004). It is not clear whether this plug that Clémençon (2004) refers to is fundamentally different from the external, lens-cap like, hyaline exudate found covering the germ-pore in many leucocoprinoid taxa (e. g. *Leucocoprinus cretaceus*, *Macrolepiota procera*). Vellinga (2001d) uses this hyaline-cap as one of the characters to distinguish two groups within the genus *Macrolepiota*.

Microchemical reaction of spores with Melzer's reagent has been extensively used as a strong character in lepiotaceous fungi where dextrinoidy (pseudoamyloidy) is the general rule. *Cystolepiota* species and species belonging to the *Lepiota* section *Lilaceae* Bon (e.g. *Lepiota apetelia* Vellinga & Huijser, *L. cristatoides* Einhellinger, *L. lilacea* Bresadola) have

weakly dextrinoid to almost inamyloid spores. Further exceptions to the rule are taxa with amyloid spores that Singer (1986) classified under the sections *Amylosporae* and *Amyloideae* currently under *Tricholomataceae* (Miller *et al.* 1996; Vellinga 2003a). Cresyl blue reacts with spore-wall of certain species and differentially stains the endosporial wall-layer (Singer 1986). Such a metachromatic spore-wall reaction (evident by a pinkish colouration) is exclusive to the leucocoprinoid members of the group and helps distinguish them from the lepiotean tribe in general. But, according to Vellinga (2001f), most species of *Cystolepiota* exhibit a pink inner wall in cresyl blue. However, this observation warrants further verification as it is extremely difficult to confirm true metachromatism in those taxa with minute spores. In *Chlorophyllum molybdites*, the entire spore is dyed deep blue with cresyl blue and the metachromatism of the wall seems either absent or obscured (Singer 1986). Congo red stains spore-wall red in majority of the taxa except *C. molybdites*, and Weresub (1971) suggested the use of ammoniacal Congo red for instant distinction of *Macrolepiota* from *C. molybdites*. But this diagnostic method may turn unreliable when the *C. molybdites* collections are immature with unpigmented spores. All the available literature indicates that spore-wall of lepiotaceous fungi is cyanophilous in cotton blue.

2.2.7 Basidia

Basidia are mostly clavate and usually bear four basidiospores per basidium. *Chlorophyllum hortense* (Murrill) Vellinga, *Leucoagaricus sericifer* forma *sericellatus* (Locquin) Vellinga (Vellinga 2001b) and *Macrolepiota*

clelandii, (Vellinga 2003c) are examples of two-spored taxa. The sterigmata upon which the spores are borne, may usually reach up to five (rarely seven) micrometers in length. Considering the arrangement and development of basidia in the hymenium, most taxa possess a 'paneolus subtype' of hymenial structure, whereas the 'psathyrella subtype' is characteristic of species of the genus *Leucocoprinus* (Singer 1986). In *Leucocoprinus*, the basidia are surrounded by pseudoparaphyses (pavement cells) which are of special taxonomic value. Their presence and development are highly characteristic of the genus *Leucocoprinus* and can be used to differentiate that genus from *Leucoagaricus* and *Cystolepiota* (Singer 1986; Vellinga 2001c, 2004a). The relatively short-sized, almost subglobose and somewhat inflated pseudoparaphyses of *Leucocoprinus* resemble those present in *Coprinus* Persoon and *Psathyrella* Fries. Smith (1981) and Smith & Weber (1982) use the term 'brachybasidioles' for these swollen cells in the mature hymenium.

2.2.8 Cystidia

Most lepiotaceous species have abundant cheilocystidia, but cheilocystidia are absent in a few species like *Lepiota jacobi*, *L. pseudoasperula* (Knudsen) Knudsen, *L. apatelia* Vellinga & Huijser, *L. cristatoides*, *Cystolepiota pulverulenta* (Huijsman) Vellinga and *C. seminuda* (Lasch) Bon. All members of the tribe *Leucocoprineae* invariably possess cheilocystidia. The cheilocystidia are sometimes large and conspicuous as in many *Leucocoprinus* species (e.g. *L. lacrymans*, in which the cheilocystidia

are up to 126 µm in length,) or they may be small and indistinguishable from the adjacent basidioles, like those in *Lepiota citrophylla* and *L. subincarnata* (Vellinga 2001a). Extreme variations in cystidial size could be observed within certain *Leucocoprinus* species.

Cystidial shape is an important taxonomic character at species-level. A wide range of shapes are seen. Cheilocystidia may be cylindrical, flexuose, fusiform, clavate, broadly clavate, utriform or lageniform. In several species of *Leucocoprinus*, especially in those belonging to the *Leucocoprinus badhamii* complex, apical outgrowths are seen on the cystidia. These may be short excrescences or flexuose or moniliform prolongations that may reach up to 45 µm in length, as observed in *Leucocoprinus croceovelutinus* Bon & Boiffard (Reid 1990). In a number of *Lepiota* and *Macrolepiota* species, septate cystidia are also observed intermixed with the aseptate ones.

Although most cystidia are hyaline and lack contents, some taxa possess cystidia with coloured contents (e.g. light brown to brownish red pigments in *Leucocoprinus lacrymans* and allies, yellow pigments in *Cystolepiota cystidiosa* (Smith) Bon). The cystidia of *Chlorophyllum molybdites* contain greenish pigments of unknown chemical composition. The contents of cystidia belonging to the *Leucocoprinus badhamii* complex react with ammonia and exhibit a greenish colour change. Similar reactions are also shown by cystidia of certain species like *Lepiota viriditincta* (Berkeley & Broome) Saccardo on drying or as a response to touch.

Cystidia in a majority of lepiotaceous taxa have slightly-thick walls, but thin- as well as thick-walled (up to 1 µm) ones are also encountered. In a few taxa like *Leucoagaricus crystallifer* Vellinga, *L. menieri* (Saccardo) Singer, and *L. rubrotinctus*, certain crystalline exudates are found sticking on to the walls, concentrated mostly towards the cystidial apex.

Pleurocystidia are generally absent in lepiotaceous fungi although their occurrence has been recorded in a few species like *Leucoagaricus barssii* (Zeller) Vellinga, *Cystolepiota cystidiosa*, and *C. hetieri* (Boudier) Singer. Conspicuous and abundant pleurocystidia are found evenly distributed over the lamellar surface in *C. cystidiosa*.

Studies on the ultrastructural morphology of cystidia in a few genera of the *Agaricales* (*Agrocybe*, *Baeospora*, *Coprinus*, *Fayodia*, *Hypholoma*, *Inocybe*, *Megacollybia*, *Oudmansiella*, *Pluteus*, *Strobilurus*, *Volvariella*) have been carried out by Clémençon (1972, 1972a), Thielke (1972, 1978, 1982), McLaughlin (1974), Gull & Newsam (1975), Setliff (1979), Strack & Sundberg (1981), Thaler & Gailhofer (1981), Rexer & Kost (1989) and by Waterkeyn *et al.* (1992). These investigations have contributed to the available subcellular information on cystidia which have been presented in a consolidated form by Clémençon (2004). However, these studies provide little to advance the implication of cystidial ultrastructure on the systematics of the *Agaricales* in general and the lepiotaceous fungi in particular. A review of the existing ultrastructural works on the cystidia reveal that the sterile cells in the hymenium of lepiotaceous fungi have not yet been the subject of any

ultrastructural study and that no data on its subcellular composition has been generated so far. As Clémençon (1975) in his comparative investigations of the hymenial cells in two Bolete species states, the information derived on these cells could be of interest to the taxonomist. Ultrastructural information obtained on the cystidia of lepiotaceous fungi could serve a taxonomic purpose as well and primary attempts in that directions needs to be initiated.

2.2.9 Trama

In lepiotaceous fungi, the lamellar trama is always regular to subregular, made up of cylindrical, thin-walled hyaline hyphae. In leucocoprinoid taxa, the hyphae that compose the lamellar trama are less inflated near the subhymenium, and gradually become highly inflated towards the tramal core. Normal hyphae uninflated are also found intermixed, but are mostly confined to the subhymenium. Such a trama is referred to as 'alveolate' (Sathe 1980) or as 'trabecular' (Vellinga 2001g). Heinemann (1989) describes such a hymenophoral trama in *Macrolepiota* as intersected, lacunose and auriferous. This tramal structure seems characteristic of the tribe *Leucocoprineae*. Species of the lepiotoid tribe strictly lack a trabecular trama although slightly inflated hyphae may be present in the trama. All lepiotaceous taxa have a cellular (pseudoparanchymatous) subhymenium.

Pileal trama is composed of interwoven cylindrical hyphae that are mostly thin-walled. In leucocoprinoid taxa, the hyphae that constitute the

pileal trama are mostly inflated in comparison with that of the lepiotoid members.

2.2.10 Pileal covering

Nature of the covering layer of pileus is extremely important in lepiotaceous taxonomy. It is a very useful character to classify taxa at the generic and infrageneric levels and even species-level delimitations are aided by a study of the constituent elements. The covering tissues found in the lepiotaceous fungi often form a separate layer. It was believed to be part of or developing from the universal veil in *Lepiota clypeolaria* (Bulliard) Kummer (Atkinson 1914), but Reijenders (1975) after studying the ontogenetic pattern of the pileal surface in a few more lepiotaceous taxa expressed difficulty in reaching a definite conclusion. According to him (Reijenders 1975), it is difficult to decide whether this layer belongs to the universal veil or to the pileipellis. Further studies are needed to verify the exact ontogeny of the covering layer of pileus. Vellinga (2001g) exercises caution and prefer usage of the neutral term 'pileus covering' for this structure in lepiotaceous fungi.

The different types of pileal covering observed in the group are: 1) A cutis made up of compactly arranged repent hyphae as in *Lepiota viridiflava* Petch or of hyphae that may be disrupted and ascending as in *L. viriditincta*. Many *Leucoagaricus* and *Leucocoprinus* species have such a cuticular covering layer. 2) A trichodermial pileal covering is characteristic of many taxa (e.g. *Lepiota citrophylla*, *L. xanthophylla*, *L. subincarnata*, the genus

Macrolepiota, *Leucoagaricus leucothites*, *Leucocoprinus meleagris*). In several sections of *Lepiota*, the erect cylindrical or fusoid terminal pileal elements making up the trichodermium are subtended by a compact layer of short clavate elements. The pileal covering is a trichodermial palisade in *Lepiota metulaespora* (Berkeley & Broome) Saccardo. 3) A hymeniderm of compactly arranged clavate terminal elements are present in taxa like *Lepiota cristata* (Bolton) Kummer and *L. lilacea*. 4) In *Lepiota* section *Echinatae*, the pileus is covered with aggregations of loosely attached chains of ellipsoid to almost globose elements borne on normal pileal hyphae. 5) *Cystolepiota* species are characterized by loosely arranged inflated globose elements intermixed with normal pileal hyphae. Although commonly recognized pileipellis types like a cutis, trichodermium, hymeniderm and epithelium are found, transitions of all kinds that do not exactly fit into any typical category are also observed.

Plasmatic, membrane and encrusting pigments are present in pileal hyphae, either singly or in combination and the pigmentation type is considered characteristic of many lepiotaceous species. For example, the pigmentation type of pileal elements is used as one of the characters to separate the two closely related species *Lepiota hystrix* Møller & Lange and *L. calcicola* by Vellinga (2001a).

The pileal covering and its ontogeny in a few species of lepiotaceous fungi have been studied only by employing the light microscope (Atkinson

1914; Reijnders 1975; Clémençon 1997), but ultrastructural studies on the pileal covering of the *Agaricales* in general are lacking.

2.2.11 Stipe covering

A number of taxa possess differentiated elements in stipe covering. When present, the differentiated elements of stipe covering is mostly similar to those of the pileal covering of that particular species. In taxa like *Chlorophyllum*, a covering with differentiated elements is absent over the stipe. Nature of the stipe surface is considered as one of the characters by Vellinga (2001d) to distinguish distinct groups within *Macrolepiota*.

2.2.12 Clamp-connections

Clamp-connections are present in most species of *Cystolepiota*, *Lepiota* and *Macrolepiota*, but are extremely rare in *Clarkeinda*, *Leucoagaricus* and *Leucocoprinus*. *Chlorophyllum molybdites* was considered as clampless (Singer 1986; Wasser 1993), but, the rare presence of clamp-connections in this taxon now stands verified (Sundberg 1971b; Vellinga 2001e).

In brief, although the group generally exhibit wide range of character variations, characters of the spores, like the presence of germ-pore and the microchemical reaction of spore-wall with cresyl blue are considered important for distinctions at the tribal level. The structure and hyphal constitution of the trama give tribe-level taxonomic indications. Characteristic colour reactions of the basidiomata, features of the pileal surface and pileal

elements, size, shape, and microchemical reactions of spores and nature of germ-pore are considered as major criteria for infrageneric classifications. Colour of basidiomata seems to be a very helpful and highly employed character at species-level identifications along with other distinguishing characters.

2.3 Genera of lepiotaceous fungi

2.3.1 *Chlorophyllum*

The genus *Chlorophyllum* was originally erected by Massee (1898), with *Chlorophyllum esculentum* Massee (= *Chlorophyllum molybdites* (Meyer) Massee) as the type species, and this genus name now stands conserved (Vellinga & de Kok 2002). The name Chlorophyllum indicates the characteristic green-spored nature of its constituent taxa. The genus has a cosmopolitan distribution but is mainly pantropical (Guzmán & Guzmán-Dávalos 1992). It often fruits gregariously, occasionally forming typical fairy rings (Vellinga 2001e; Hemmes & Desjardin 2002). They have large fleshy basidiomata resembling those of the genus *Macrolepiota* but differ by the greenish lamellae and green spore-prints. This separation based on spore-print colour, however is now disputed (see Vellinga 2003b, 2004a: 374, 375). The basidiomata are highly poisonous but reports of exceptional edibility have also been registered (Graff 1927; Singer 1969, 1986; Guzmán & Guzmán-Dávalos 1992; Wasser 1993). Innumerable references on this agaric could be found in lepiotaceous literature.

2.3.1.1 Genus-concept

Until the genus *Chlorophyllum* was conceptualized, the genus *Agaricus* and later *Lepiota sensu lato* were found to be used by earlier workers to place the distinct green-spored taxa currently placed in *Chlorophyllum*. The names *camporum*, *chlorospora*, *esculenta*, *guadelupensis*, *molybdites*, *morgani* or ochrospora were used by them to refer to the species currently recognized as *C. molybdites* (Graff 1927; Vellinga 2001e). A majority of mycologists consider the various specific names proposed for green-spored agarics as synonyms (Dennis 1970; Guzmán & Guzmán-Dávalos 1992; Singer 1969; Vellinga 2001e; Vellinga 2006) and consequently *Chlorophyllum* to be monotypic (Sundberg 1968; Pegler 1977), though extreme variability within the taxa had been admitted (Heinemann 1968; Singer 1986; Ghosh *et al.* 1976). Singer (1986) on the basis of edibility distinguishes two species, a poisonous *C. molybdites* and edible *C. esculentum*. Vellinga & de Kok (2002) accepted four species, after accepting three more newly described species, two from India (Sathe & Kulkarni 1980) and one from Madagascar (Heinemann 1968). But the fact that those new species have never been found recollected and studied, after their original description, makes one skeptical to accept them on a par with *C. molybdites*.

Recently, combined morphological and molecular studies (Johnson 1999; Vellinga *et al.* 2003) supported the insertion of a section of *Macrolepiota* (*Laevistipedes* (Pázmány) Bon) within *Chlorophyllum*, thereby

expanding the scope of the genus. Vellinga & de Kok (2002), based on these modern phylogenetic inferences, formally proposed the genus name *Chlorophyllum* for the clade that contained *Macrolepiota* section *Laevistipedes* and *C. molybdites*, thereby also rejecting as erroneous, the opinion of some authors to include *C. molybdites* in *Macrolepiota* section *Laevistipedes*. According to the amended concept (Vellinga 2003c), the genus *Chlorophyllum* has a hymeniform pileal covering, smooth stipe, and spores with germ-pore formed by a depression in the episporium and without a hyaline cap. On these grounds, Vellinga (2002) proposed 13 new combinations in *Chlorophyllum*. As a result of this transfer, the well-known *Macrolepiota rachodes* species-complex and many other related species (e.g. *M. globosa* Mossebo, *Leucoagaricus hortensis* (Murrill) Pegler), now stand shifted to *Chlorophyllum sensu* Vellinga. Pegler & Young (1971) had earlier predicted a similar revision of the systematic position of *M. rachodes* based on ultrastructural observations.

2.3.1.2 Phylogeny

Phylogenetic analyses (Vellinga *et al.* 2003; Vellinga 2004a) indicate placement of the genus with members of *Macrolepiota* section *Laevistipedes*, *Endoptychum agaricoides* Czernajew and *Leucoagaricus hortensis*. They settle as a clade closer to the brown-spored genus *Agaricus* than to other white-spored leucocoprinoid genera. Members belonging to this clade have similar morphological characters and are placed under the genus *Chlorophyllum sensu* Vellinga (Vellinga 2002, 2003c).

2.3.2 *Clarkeinda*

With its rather remarkable combination of characters, *Clarkeinda* has a unique position within the family *Agaricaceae*. The large agaricoid basidiomata of this genus are distinct with a thick cartilaginous pellicle at the pileal disc, a fixed annulus, and a persistent membranous volva. The green spore-print, the almost amygdaliform spores with a distinct germ-pore, and the orthochromatic reaction of spores with cresyl blue are reminiscent of the chlorosporic genus *Chlorophyllum* (Pegler 1985). However, the structure of the pileus covering, which is a trichodermial palisade, indicates affinities with *Hymenagaricus* Heinemann (Pegler 1985). With a distribution limited to south-east Asia (Pegler 1985), this monotypic genus is unfamiliar to most western mycologists. However, sufficient taxonomic details on this tropical fungus are available from the works of Petch (1908), Boedijn (1934), Pegler (1985, 1986), Leelavathy *et al.* (1981) and Singer (1986). The first two of these authors used the name *Chitoniella* Hennings for this genus. Etymology of the genus name *Clarkeinda* refers to Charles Baron Clarke, a former Kew botanist, and also to India (Donk 1962; Pegler 1985). *Clarkeinda trachodes* (Berkeley) Singer (= *Agaricus pedileus* Berkeley & Broome) is the designated type species.

2.3.2.1 Genus-concept

The genus was erected to accommodate an agaric species collected from Sri Lanka, which was initially considered as a member of the genus *Agaricus* subgenus *Psalliota* (Fries) Loudon and then as a member of

Agaricus subgenus *Chitonia* Fries. It was later transferred to another genus *Chitoniella* (see Pegler 1985). Singer (1986) accepted *Clarkeinda* as a good genus inside the family *Agaricaceae* and considered it close to the genus *Chlorophyllum* of the tribe *Leucocoprineae*. At the same time he recognized its main differentiating characters like the presence of a volva and smaller spores. Similarities of *Clarkeinda* with a section of *Agaricus* have been noted by Singer (1986), and Pegler (1985) highlights its close relationship with *Hymenagaricus*. *Clarkeinda* remains a monotypic genus.

2.3.2.2 Phylogeny

Although its placement inside the *Agaricaceae* is confirmed (Pegler 1985; Singer 1986), the precise relationships of *Clarkeinda* within the family are unknown. According to the morphology-based observations of Pegler (1985), the genus occupies a position intermediate between the tribes *Agariceae* and *Leucocoprineae*, and the genus could be suggested as a connecting link between the two tribes. But further investigations, including molecular analyses are necessary to substantiate this view and to clearly understand the phylogenetic relationships of this tropical genus.

2.3.3 *Cystolepiota*

Cystolepiota is a rather recently-recognized genus closely allied with a section of *Lepiota sensu stricto*. A close relationship with the genus *Melanophyllum* with coloured spores is also suggested (Vellinga 2001f). Basidiomata of *Cystolepiota* are characterized with striking, warty to conical

pileal scales or a distinctly mealy-powdery to floccose pileal and stipe surfaces. The hyaline, inamyloid spores without a germ-pore, and a pileal covering made up of somewhat loosely arranged globose to oblong or elongate, inflated elements (Vellinga 2001f) distinguish them microscopically. The genus has a world-wide occurrence with more diversity in the tropics and subtropics and occassional reports from the Arctic-alpine habitats (Peintner & Horak 1999). The known European species have been compiled with keys (Candusso & Lanzoni 1990; Bon 1996; Vellinga & Huijser 1998, 2001f), but tropical species remain inadequately studied.

2.3.3.1 Genus-concept

Singer (in Singer & Digilio 1952) introduced this genus, initially, for four *Lepiota* species having an epithelial pileal covering and inamyloid spores. The genus-concept was further expanded when Singer & Clemençon (1972) and Bon (1977) shifted some more species from *Lepiota* section *Echinatae* (see Knudsen 1978: 135). Singer (1986) stressed the configuration of the epicutis (exclusively made of sphaerocysts) and the always or mostly uninucleate and inamyloid spores to separate the genus from *Lepiota sensu* Singer. He also pointed out that the number and type of intermediate sphaerocyst cells may also prove informative in generic demarcation. Later, Knudsen (1978) revised the genus *Cystolepiota* to include all *Lepiota* species with an epithelial pileal covering. This involved transferring the whole of *Lepiota* section *Echinatae* that mostly contained species having dextrinoid and binucleate spores. But after examining more

species of the group, Knudsen (1980) reversed this opinion, citing the importance of limiting *Cystolepiota* species to include only taxa with uninucleate spores and without intermediate cells in the pileal covering.

Within the genus *Cystolepiota*, Singer (1986) considered two sections, *Cystolepiota* Singer and *Pseudoamyloideae* Singer & Clémençon. The section *Pseudoamyloideae* includes species with dextrinoid spores while the remaining species are maintained inside the section *Cystolepiota*. Knudsen (1978) divided the genus into four sections (*Cystolepiota*, *Echinatae* (Fayod) Knudsen, *Pseudoamyloideae* and *Floccosae* Knudsen). Knudsen (1980) later removed the section *Echinatae* from *Cystolepiota*. Candusso & Lanzoni (1990) treated 11 species under two sections (*Cystolepiota* & *Pseudoamyloideae*). The section *Cystolepiota* in their work was further classified into subsections, *Minutae* Candusso, *Floccosinae* (Knudsen) Bon and *Cystidiosinae* Bon. Bon (1996) also treated the European species he studied under the two above sections, but subdivided the section *Cystolepiota* into subsections *Seminudae* Lange ex Bon, *Floccosinae* and *Cystidiosinae*. Revisionary studies on the genus by Vellinga & Huijser (1998) introduced a third and new section, the *Pulverolepiota* Bon (Vellinga) (= genus *Pulverolepiota* Bon) that includes the species *C. pulverulenta*.

2.3.3.2 Phylogeny

Combined morphological and molecular analyses by Johnson (1999) supported the transfer of *Lepiota* section *Echinatae* to *Cystolepiota*

supporting Knudsen's (1978) view. This finding is strongly supported by further molecular studies by Vellinga (2003a, 2004) who suggested a separate genus for *Cystolepiota*, *Lepiota* section *Echinatae*, *Melanophyllum* and *Pulverolepiota* combined.

2.3.4 *Lepiota*

The name *Lepiota*, derived from a Greek word λεπίς which means 'scale', is aptly given to a set of species with conspicuously scaled basidiomata. The wide range of characters exhibited by this genus makes species-level identification difficult. The species has a cosmopolitan distribution.

2.3.4.1 Genus-concept

According to Donk (1962) the first author to use the name *Lepiota* was J. Hill in the year 1751, giving the name to all stalked fungi. In 1801, Persoon published the name *Lepiota* as a section of the genus *Agaricus*, for the first time for species having an annulate stipe, free lamellae, and innate scales on the pileus. As per its original conception, *Lepiota* included, irrespective of the spore colour, most members of the genus *Agaricus* with an annulus and without a volva. The name *Lepiota* was limited to white-spored species by Fries (1821) and he assigned it as a tribe of *Agaricus*. Non-concrescence of the pileal and stipe tissues and that of the pileal cuticle and universal veil were characters that received particular attention from Fries although exceptional cases were there (see Lange 1915). Gray (1821)

was the first to raise the group to the generic level. Gray's genus *Lepiota* corresponds to the Friesian tribe *Lepiota*.

Berkeley & Broome (1870) documented 67 species of *Lepiota* from Sri Lanka. A monographic documentation of North American species was made by Morgan (1906, 1907). More inclusive accounts based mainly on macroscopic characters appeared when Murrill (1914) recorded a total of 97 species in his treatise on North American agarics, of which some species were later found to better fit in the genus *Limacella*.

Incorporation of microscopic characters in agaric taxonomy from the later part of the 19th century onwards improved circumscriptions of taxa and aided species-level identifications. By including characters like shape and size of spores, presence, form and size of cystidia, and the nature of pileal surface, Lange (1915) propounded a classification which was an improvement over the basic Friesian arrangement. The genus *Lepiota* was divided into three main tribes, *Procerae* Fries, *Clypeolariae* Fries and *Granulosae* Fries, retaining the Friesian names in a somewhat extended sense and rearranging and excluding a few species earlier considered by Fries. Lange's tribe *Procerae* was distinguished by large ovate spores and a free ring, *Clypeolariae* by fibrillose or floccose pileal coating and pointed, narrow spores, and *Granulosae* by conical, erect or granular warty pileal squamules partly or entirely made up of globular cells, and small spores (less than 8 µm long). Lange (1915) cautiously mentioned that his

classification system was based on observations of only 30 species studied by him.

Distributing the known species into seven sections based mainly on velar characters, Kauffman (1924) introduced another infrageneric classification for the genus. Species with a glutinous veil covering the young basidiomata were placed in the section *Lubricae*. Members with viscid pileal surface and a dry stipe were placed in the section *Viscidae*. Section *Pruinosae* was characterized by species with floccose or granular elements on pileal and stipe surfaces and with an evanescent annulus. The presence of a distinct and persistent annulus, smooth stipe, and a scaly pileal cuticle distinguished species under the section *Subclypeolariae*. Species kept under the section *Clypeolariae* had a well-developed veil, coloured fibrillose or floccose scales on both pileus and stipe, and an evanescent annulus. Section *Asperae* was erected to include species with a thick, loose, fibrillose universal veil covering the young fruit bodies which upon expansion breaks up into erect scales and a fine fibrillose partial veil. Large basidiomata, well-developed membranous annulus, and scaly, fibrillose or rarely glabrous pileii characterize the section *Procerae-Annulosae*.

Kühner's (1936) study, with thorough observations on many taxonomically valuable characters, resulted in recognition of 14 sections in *Lepiota*; those with a divergent trama earlier kept in *Lepiota* were relocated in to the genus *Limacella*. The sections identified were: *Striatae* Murrill, *Echinatae* Fayod, *Micaceae* Lange, *Granulosae*, *Sericellae*, *Lepiotellae*

Kühner, *Integrellae*, *Procerae*, *Cristatae*, *Pilosellae*, *Annulosae*, *Stenosporae* Lange, *Clypeolariae*, and *Ovisporae* Lange.

Locquin (1945b) limited the genus-concept to eight subgroups, after shifting some members to the genera *Cystoderma* and *Leucocoprinus*. The subdivisions proposed accordingly for *Lepiota* were *Echinoderma*, *Lepiotula* Maire, *Integrella*, *Eulepiota* Locquin, *Lepiotella*, *Micacystis*, *Sericella* and *Pilosella*. Locquin's *Eulepiota* approximately corresponds to Kühner's (1936) sections *Annulosae*, *Stenosporae*, *Clypeolariae* and *Ovisporae*. Species with spurred spores, once kept in *Lepiota* section *Stenosporae* (Lange) Kühner, were grouped by Locquin inside *Lepiotula*. This subcategory *Lepiotula* is sometimes found referred to as a genus name although not generally approved (see discussion by Donk 1962: 167). Horak (1980a) accepted *Lepiotula* (Maire) Locquin ex Horak as a distinct genus after transferring some species of *Lepiota* to and describing a few new species in that genus.

In '*Flore analytique des champignons supérieurs*', Kühner & Romagnesi (1953) categorized species of the group into *Lepiotellae*, *Integrellae*, *Seminudae* Lange, *Clypeolariae*, *Annulosae* and *Procerae*. *Lepiotellae* was represented by a single species, *L. irrorata* Quélet. The group *Lepiotellae* equals the genus *Lepiotella* (E. J. Gilbert) Konrad. *Clypeolariae* was divided into four groups: *Echinatae*, *Stenosporae*, *Ovisporae* and *fusisporae* Lange. *Annulosae* included the groups *Rubentes* Kühner, *Striatae* and *Pudicae* Kühner. They recorded the use of cresyl blue for separating many species within the genus which resulted in

distinguishing *Annulosae* and *Procerae* as groups of species having porate spores along with a metachromatic endosporium in cresyl blue. The groups *Annulosae* and *Procerae* roughly represent the present-day genera *Leucocoprinus* and *Macrolepiota* respectively.

Dennis (1952) provided a significant contribution to the study of lepiotas by describing 35 species that he collected from the West Indies. He placed all those species inside the single genus *Lepiota* and did not recognize the genus *Leucocoprinus*. But, in his following contribution on fungi from Venezuela, Dennis (1961) seems to have accepted the generic segregation.

A general agreement on the genus composition was lacking for want of definitive morphological markers. Uncertainties regarding the type species also compounded the confusion over an appropriate genus-concept (Johnson 1999). Earle (1909) considered *Agaricus procerus* (Scopoli) Fries as the lectotype as that species was the first mentioned by Persoon (1794). Singer & Smith (1946) selected *A. colubrinus* Persoon for Gray's *Lepiota*. Singer (1951) strongly favoured the selection of *A. colubrinus* and maintained that with *A. colubrinus* as the type species, a greater number of combinations could be avoided and according to him, *A. procerus* belonged to a separate genus, the *Macrolepiota*. Earle's view was supported by Donk (1962) who added a few other reasons in defense although he was aware of Singer's arguments against *A. procerus*. Rauschert (1986) formally proposed *Lepiota colubrina* (Persoon) Gray as the type species with adequate

reasons. This designation is now conserved (Greuter *et al.* 1994) as already pointed out by Johnson (1999).

The wide genus-concept of *Lepiota* continued to get general acceptance until enhanced understanding on the macro and microcharacters resulted in narrower generic concepts such as those followed by most recent lepiotologists. The new restricted genus-concepts (Singer 1986, Bon 1996) pruned down *Lepiota* by removing taxa that now belong to smaller and segregate genera like *Cystolepiota*, *Leucoagaricus*, *Leucocoprinus* and *Macrolepiota* based on more reliable differentiating characters. Singer's (1986) concept of *Lepiota*, gained wider appreciation and acceptance owing to its comprehensiveness both in character as well as species selection. Singer essentially based his infrageneric classification on Kuhner's (1936) system.

Singer (1986) classified the genus *Lepiota* into eight sections. Section *Echinatae* included species with a spiny or wooly-squamose pileal surface made of mostly globular elements (sphaerocysts) at the spiny scale tips, dextrinoid spores, and clamp connections. Section *Amyloideae* Singer is characterized by a pileus with woolly-squamose covering, amyloid spores, clamp-connections, and intracellular pigments. The single species (*Lepiota lignicola* Karsten) recognized by Singer under the section *Amyloideae* is now accommodated under the genus *Leucopholiota* (Romagnesi) Miller, Volk & Bessette in *Tricholomataceae* (Miller *et al.* 1996; Vellinga 2003a). Species belonging to the section *Cristatae* Kühner posses a hymeniform pileal cuticle

that ruptures into scales or areolae or else split longitudinally over most of the pileal surface. Section *Stenosporae* is distinguished by a palisadal pileal cuticle with essentially erect hyphal elements, and with strongly spurred or distinctly truncate spores. Section *Lepiota* is characterized by species that have palisadal pileal covering and large fusoid spores. A palisade of more or less erect hyphal elements, non-fusoid spores (less than 10 µm long), well-developed or obsolete and fugacious annulus and hyphae with clamp-connections qualify placement in the Section *Ovisporae* (Lange) Kühner. Taxa having dextrinoid spores but lacking clamp-connections were placed in the section *Anomalae* Locquin. Species belonging to the section *Amylosporae* Singer have amyloid spores and hyphae without clamp-connections.

Candusso & Lanzoni's (1990) comprehensive monographic work on *Lepiotas* of Europe lists 66 species of *Lepiota sensu stricto*. They categorized these 66 species of *Lepiota* into six sections. Section *Echinatae* Fayod emend. Knudsen is composed of 11 species. Section *Lepiota* is divided into two subsections, *Latisporinae* (2 spp.) and *Lepiota* (10 spp.). Thirteen species with spurred spores are placed in section *Stenosporae*, The section *Ovisporae* (Lange) Kuhner has a subsection *Helveolinae* Bon & Boiffard with five species, and 15 species are placed in the subsection *Felininae*. Section *Fuscovinaceae* Bon & Candusso is distinguished by one species and section *Lilaceae* Bon is further classified into subsection

Lilaceinae Bon with six species and subsection *Integrellinae* Kuhner ex Bon with three species.

As Vellinga (2003a) stated, Bon (1996) applied the narrowest genus-concept of all. Bon (1996) divided the genus into three subgenera: *Lepiotula* (Maire) Locquin ex Horak emend., *Lepiota* and *Paralepiotula* Bon. Subgenus *Lepiotula*, distinguished by species having spurred spores, is subdivided into two sections, *Cristatae* (Kuhner ex Wasser) and *Stenosporae* (Lange) Kuhner. These two sections were separated on the basis of a strict hymeniform pileal covering of the former and a trichodermial pileal covering of the latter. Subgenus *Lepiota* incorporates four sections: *Lepiota*, *Helveolae* (Bon & Boiffard) Bon, *Fuscovinaceae* M. Bon & Candusso and *Felinae* (Bon) Bon. The section *Lepiota* characterized by species with ellipsoid to spindleform spores consists of two subsections, *Latisporinae* Bon and *Fusisporinae* (Lange) Bon. Section *Helveolae* is further divided into subsection *Helveolinae* Bon & Boiffard, comprised of members showing a positive reaction with ammonia and spores that are non-metachromatic in cresyl blue and *Parvannulatae* Bon by species showing negative reaction with ammonia and spore-wall not metachromatic in cresyl blue. The species, *Lepiota parvannulata* (Lasch: Fries) Gillet and closely related *L. nigrescentipes* Riousset, which Bon kept under section *Parvannulatae* was admitted to section *Ovisporae* subsection *Helveolinae* by Vellinga (2001a). Bon's Section *Felinae* is split into three subsections, *Felininae* Bon, *Brunneoincarnatae* Bon and *Paralilaceae* Bon. Subgenus *Paralepiotula* is

divided into two sections, *Lilaceae* Bon and *Integrellae* (Kühner ex Bon) Bon. Bon (1996) considered a total of 75 European species in his infrageneric classification of *Lepiota sensu stricto.*

Vellinga (2001) recognized six sections to distribute the 46 *Lepiota* species that she studied from the Netherlands. Species with fusoid spores and a trichodermial pileal covering made up of long cylindrical elements intermixed with short cells were placed in the section *Lepiota*. Species bearing spurred spores and ascending or erect trichodermial pileal elements belonged to *Stenosporae* (Lange) Kühner. Section *Ovisporae* (Lange) Kühner with ellipsoid to oblong spores and a trichodermial pileal covering was divided into subsections *Helveolinae* Bon & Boiffard with trichodermial pileal covering of only long, cylindrical elements and *Felininae* with pileal covering made of long, cylindrical and short clavate elements. *Fuscovinaceae* Bon & Candusso, *Lilaceae* M. Bon and *Echinatae* Fayod were the other sections distinguished in that work.

2.3.4.2 Phylogeny

Johnson & Vilgalys (1998) and Johnson (1999) presented molecular evidences indicating paraphyly to *Lepiota sensu stricto.* The polyphyletic nature of *Lepiota* was also evidenced from a molecular study on euagarics by Moncalvo *et al.* (2002). However, DNA-based investigations by Vellinga (2003a, 2004a) indicated monophyly for *Lepiota* along with *Lepiota* section *Echinatae*, *Cystolepiota*, *Melanophyllum* and *Pulverolepiota*. According to her analyses, section *Echinatae* of *Lepiota* settled as a distinct clade

independently along with *Cystolepiota*, *Melanophyllum* and *Pulverolepiota*. Her studies revealed that species with non-spurred spores has to be included in the section *Stenosporae* and that section *Ovisporae* is not a monophyletic group.

2.3.5 *Leucoagaricus*

The genus *Leucoagaricus* incorporates many of the white-spored lepiotaceous fungi, which macroscopically resemble the genus *Agaricus*. Singer (1948a) validly published the name *Leucoagaricus* Locquin as a genus name, which was initially *Leucocoprinus* subgenus *Leucoagaricus* Locquin. *Leucoagaricus* Locquin is synonymous with *Lepiota* subgenus *Leucobolbitius* (Lange) Locquin. Both these earlier names had been rejected for the genus on grounds of invalid publication (see Donk 1962: 171,172).

Leucoagaricus macrorhizus was originally designated as the type species by Locquin. Later, Reid (1998) considered *L. macrorhizus* as a synonym of *L. pinguipes* (A. Pearson) Bon. Vellinga (2000a) found another older species *L. barssii* Zeller, from the *macrorhizus-pinguipes* species complex as synonymous with *L. pinguipes* and argued for priority for the specific name - *barssii*. Vellinga justified her new combination citing extreme morphological and molecular similarities between the species.

Singer (1969) reported four *Leucoagaricus* species from Australia. Eleven new species were described by Heinemann (1973, 1979) from Africa. At about the same time, a few species were transferred and described by

Bon & Boiffard (1974) from France into Locquin's *Leucoagaricus*. Moser (1983) lists 13 *Leucoagaricus* species from Europe. Singer (1986) recognized 26 species of *Leucoagaricus*. Other major contributions were those of Candusso & Lanzoni (1990), Wasser (1993), Bon (1996) and Vellinga (2001b) who admitted 40, five, 48 and 21 species respectively.

In addition to the major works cited above, several scattered and independent reports on the genus were made by mycologists from around the world (e.g. Pegler 1977, 1983; Heinemann 1981; Babos 1981, 1985, 1995; Migliozzi & Perrone 1982; Urbonas *et al.* 1986; Migliozzi *et al.* 1989b; Reid 1998; Reid & Eicker 1993a; Britenbach & Kranzlin 1995; Lange 1995; Akers & Sundberg 1997; May & Wood 1997; Akers *et al.* 2000; Migliozzi & Resta 2000; Hemmes & Desjardin 2002). Reid (1995) gave comprehensive observations and discussion with keys to *Leucoagaricus melanotrichus* (Malençon & Bertault) Trimbach and similar species. Recently, a volvate species, *L. bivelatus* similar to *L. volvatus* Bon & Caballero was discovered and described as new from Panama by Akers & Ovrebo (2005).

A survey of the sporadic reports reveals that the genus is relatively lesser documented and studied. It also indicates a much higher diversity of the genus in the warmer zones. A critical monographic treatment of the genus is imperative as commented by Wasser (1993) and Vellinga (2001b).

2.3.5.1 Genus-concept

Singer (1948a) transferred a number of species of *Lepiota sensu lato* that were characterized by spores metachromatic in cresyl blue and often with a germ-pore to *Leucoagaricus* while classifying the more or less heterogeneous group intermediate between the genera *Leucocoprinus* and *Macrolepiota*. Although separated from the latter two genera, a clear-cut genus-concept for *Leucoagaricus* has not yet been achieved as the genus characters proposed exhibit a very high level of overlapping within the lepiotaceous genera. A group of species, known as the 'rubentes group' (Babos 1979) or the 'badhamii complex' (Reid 1990) that turn reddish upon bruising and which exhibits a greenish colouration on exposure to ammonia fumes too is being shuttled back and forth between *Leucoagaricus* and *Leucocoprinus* (Vellinga 2004a; Kumar & Manimohan 2004). Workers like Bon (1996), Candusso & Lanzoni (1990) and Vellinga (2001b) follows the former while Babos (1979), Moser (1983), Reid (1990) and Wasser (1993) accept the latter placement for the species-complex.

Heinemann (1969) clarified his concept of *Leucoagaricus* by limiting the genus to species possessing moderately thin-walled spores not exceeding 11 µm in length and with a reduced germ-pore.

Many species (e.g. *Leucoagaricus serenus* (Fr.) Bon & Boiffard and *La. gauguei* Bon & Boiffard) considered under *Leucoagaricus* were transferred to *Sericeomyces* when Heinemann (1978) elevated *Lepiota* section *Sericellae* Kühner to the generic rank. More taxa were later shifted to

Sericeomyces by workers like Contu (1991) and these transfers gained support even from Singer (1986) and Bon (1996). However, Candusso & Lanzoni (1990) and Vellinga (2000b) took a conservative approach, and treated *Sericeomyces* as a subgenus of *Leucoagaricus*. Wasser (2002) questioned the validity of Heinemann's segregation and molecular investigations (Vellinga 2004a) now seem to reject the monophyly of *Sericeomyces*, a genus characterized with a silky pileal surface composed of radial filamentous hyphae (Guzmán & Guzmán-Dávalos 1992; Wasser 2002). Pegler (1983, 1986) used the name *Leucoagaricus* in a very restricted sense placing many species otherwise considered under *Leucoagaricus* in *Lepiota sensu stricto* (sections *Cristatae*, *Ovisporae*, *Sericellae*) (Vellinga 2004).

Singer (1986) considered six sections (*Annulati* (Fries) Singer, *Rubrotincti* Singer, *Sculpturati* Singer, *Leucoagaricus* Singer, *Piloselli* (Kuhner) Singer and *Sphaerocystophori* Singer) within the genus. Candusso & Lanzoni (1990) divided the genus *Leucoagaricus* into subgenus *Leucoagaricus* and subgenus *Sericeomyces*. The 38 species that they studied under subgenus *Leucoagaricus* were again subgrouped into five sections (*Leucoagaricus*, *Pulverulenti*, *Rubrotincti*, *Pilosellae*, *Annulati*). Bon (1996) recognized four sections (*Leucoagaricus*, *Annulati*, *Piloselli* and *Rubrotincti*) and further classified the species inside subsections (section Leucoagaricus: subsection *Leucoagaricus* Bon and subsection *Melanotrichi* Bon; section *Annulati*: subsection *Rubescentes* (Wasser) Bon and

subsection *Annulosi* (Fries) Bon; section *Piloselli* subsection *Piloselli*: Bon and subsection *Pilatiani* Migliozzi & Perrone; and section *Rubrotincti*: subsection *Trichodermi* Bon & Migliozzi and subsection *Rubrotincti* (Singer) Bon).

A phylogenetically sound infrageneric classification is yet to be proposed for *Leucoagaricus* and the few existing ones seem to be premature, as many unrelated species are grouped together while closely related ones are split into different sections (Vellinga 2001b).

2.3.5.2 Phylogeny

Bon (1996) speculated a possible evolution of the genus *Leucoagaricus* from a putative *Sericeomyces* (= *Lepiota* section *Sericellae* of Kühner) which he believed in turn to have been derived from the *Lepiota* section *Parvannulatae* (of Bon) lineage. Molecular investigations (Johnson 1999; Vellinga 2004a) reveal *Leucoagaricus* to be paraphyletic, but together with *Leucocoprinus* and including the polyphyletic *Sericeomyces*, forms a large monophyletic clade. A definitive phylogenetic inference seems premature from these analyses for want of enough data on its members, especially from the tropics.

2.3.6 *Leucocoprinus*

Leucocoprinus is a distinct genus of the tribe *Leucocoprineae*, accepted by most modern mycologists. A general macroscopic resemblance to some species of the genus *Coprinus* (Fries) S. F. Gray *sensu lato* is

attributed (Wasser 1993), but could be kept apart from that genus mainly by the characteristically pale spore-print colour. The relatively small-sized basidiomata and the absence of clamp-connections differentiate *Leucocoprinus* from *Macrolepiota*, while it can be distinguished from *Leucoagaricus* by the fragile coprinoid basidiomata, the distinctly striate pileal margin and the abundance of pseudoparaphyses in the hymenium (Singer 1986; Vellinga 2001c, Kumar & Manimohan 2004). *Leucocoprinus cepaestipes* (Sowerby) Patouillard is the designated type species.

Although found world-wide, the members have a predominantly tropical distribution. Most reports from temperate regions are based on encounters in green houses and gardens growing tropical plants in organically manured pots indicating introduction from the warmer regions. Singer (1986) accepted 13 species while several new were described later (e. g., Migliozzi et al. 1989a; Reid 1989, 1990,). Candusso & Lanzoni (1990) and Bon (1996) also recognized 13 species. A few other noteworthy reports on the genus include those by Heinemann (1973, 1977a, 1977b), Pegler (1977, 1983, 1986), Babos (1979), Smith (1981), Smith & Weber (1982), Wasser (1993), Vellinga (2001c) and Vrinda *et al* (2003).

2.3.6.1 Genus-concept

The genus name *Leucocoprinus* was first published by Patouillard (1888) and was later accepted as valid by Singer & Smith (1946) and Singer (1951) (see discussion by Donk 1962). Before the introduction of restricted generic concepts in lepiotaceous fungi, leucocoprinoid members were

treated under different sections within *Lepiota sensu lato*. Later many mycologists, especially French, like Locquin (1945b), considered them as a separate genus in a rather wide sense by merging *Macrolepiota* and *Leucoagaricus* within *Leucocoprinus*. But a distinct generic status independent of the other related genera in the modern sense was given by Singer (1986).

Locquin (1945b) in his '*Notes sur les Lépiotes*', proposed four subgenera, *Leucoagaricus*, *Euleucocoprinus* Locquin, *Hiatula* (Fries) Montagne, and *Leucobolbitius* under the genus. His subgenera *Euleucocoprinus* and *Hiatula* together are roughly equivalent to *Leucocoprinus sensu* Singer. Heinemann (1977b) divided species under the genus *Leucocoprinus* into four sections based on spore and pileal characters. Sections *Leucocoprinus* Heinemann and *Velutipedes* Heinemann are characterized by species whose spores possess a distinct germ pore. These two sections could be differentiated by pileal features. Species with a rudimentary germ-pore is distributed in to two sections, *Pepinospori* Heinemann and *Denudati* Herink which differs based on the spore-size.

Singer (1986) restrained from subdividing *Leucocoprinus* while Candusso & Lanzoni (1990) treat the species under two sections, *Leucocoprinus* and *Denudati*. Wasser (1993) classified the genus into two subgenera, *Leucocoprinus* Wasser and *Rubescentes* Wasser, based on the change of colour of basidiomata on reacting with ammonia and, change of

colour of context on exposure or on handling. Species belonging to the subgenus *Rubescentes* turns greenish on exposure to ammonia fumes and their context becomes reddish brown on exposure or on handling. Species belonging to the 'badhamii complex' (Reid 1990) are accommodated under this division.

Bon (1996) classified the genus into two sections: *Cepaestipides* Konrad & Maublanc (with spores more than 10 (12) × 7 (8) µm and with a distinct germ-pore) and *Denudati* (spores less than 8 (9) × 6 µm and without a distinct germ-pore). Section *Cepaestipides* is composed of *Leucocoprinus cepaestipes* and its related species (Smith 1981; Migliozzi 1986).

2.3.6.2 Phylogeny

A possible phylogeny based on non-molecular data had been presented by Bon (1996), where he considered *Leucoagaricus* to be the probable ancestor of a monophyletic genus *Leucocoprinus*. Recent molecular investigations (Vellinga 2004) reveal a monophyly for *Leucocoprinus* and also together with *Leucoagaricus* and *Sericeomyces* are found to constitute one large monophyletic group. Interestingly, the molecular observations seem to support the broader generic concept of *Leucocoprinus* earlier used by mycologists like Locquin (1945b). Based on her observations, Vellinga (2004a) suggest a single genus to accommodate members of these closely related taxa (i.e. *Leucocoprinus*, *Leucoagaricus*, and *Sericeomyces*).

2.3.7 *Macrolepiota*

As the genus name denotes, members of this comparatively well-studied lepiotaceous genus are distinguished by their large-sized basidiomata. They are easily identified in the field and could be distinguished from *Lepiota sensu stricto* mainly by their size of basidiomata, presence of spores with a germ-pore and stipe with a movable annulus (Wasser 1993). *Macrolepiota* differs from the genus *Chlorophyllum* mainly by the colour of spore-print, chemical reactions of spores, development of basidiomata, ecology, and geographical distribution (Wasser 1993). Many authors (Singer 1986; Franco-Molano 1999) consider the presence of clamp-connections in *Macrolepiota* as an additional differentiating character. Vellinga (2003c) however, maintains that the distinction is solely based on the spore colour. The size of spores and the presence of a movable annulus separate *Macrolepiota* from *Leucoagaricus*. Heinemann (1969) distinguished *Macrolepiota* from *Leucoagaricus* on the basis of a simpler wall structure and reduced germ-pore development in the latter.

Except for the arctic and high alpine regions, *Macrolepiota* has a world-wide distribution (Vellinga 2001d). Although a world monograph on the genus is lacking, studies by workers like Heinemann (1969), Candusso & Lanzoni (1990), Wasser (1993), Bon (1996) and Vellinga (2001d) are thorough and rather extensive. Singer (1986) accepts 12 species as belonging to the genus while Candusso & Lanzoni (1990) accepts 20

species. Bon (1996) includes 18 species and Heinemann (1969) and Vellinga (2001d) treat eight species each.

2.3.7.1 Genus-concept

The genus *Macrolepiota* was erected by Singer (1948b) under the tribe *Leucocoprineae* (*Agaricaceae*) with *Macrolepiota procera* (Scopoli) Singer as the type species. Members now kept under *Macrolepiota* were considered by earlier workers under the name *Agaricus*, *Lepiota* or later, *Leucocoprinus sensu lato* (Ghosh & Pathak 1965; Singer 1986). These differing concepts had led to arguments in favour of designating the species '*procera*' as the type of *Lepiota*. Singer (1951) strongly opposed this view (see Donk 1962: 164) and maintained his concept that placed '*procera*' as well as many other related species under *Macrolepiota*. *Macrolepiota* is currently well-accepted as a distinct genus characterized by large basidiomata, white spore-prints, large spores that are metachromatic in cresyl blue, a movable membranous annulus on the stipe, and inconstant clamp-connections (Heinemann 1969, 1989; Krieglsteiner 1981; Pegler 1977, 1983, 1986; Pázmány 1985; Candusso & Lanzoni 1990; Wasser 1993; Bon 1996; Franco-Molano 1999; Vellinga 2001d;).

Singer (1986) proposed an infrageneric classification for *Macrolepiota*, essentially based on the presence or absence of clamp connections (Candusso & Lanzoni 1990; Vellinga *et al.* 2003). The two divisions recognized accordingly were section *Macrolepiota* (with clamp-connections) and section *Macrosporae* (Singer) Bon (without clamp-

connections). Candusso & Lanzoni (1990) followed Singer's classification of the genus into two sections, *Macrolepiota* and *Macrosporae*, and in addition identified three subsections (*Macrolepiota*, *Laevistipides* Pázmány, *Microsquamatae* (Pázmány) Bellú & Lanzoni) within the section *Macrolepiota*. Section *Macrolepiota* is identical to the section *Procerae* of *Lepiota sensu lato* (Wasser 1993; Bon 1996). Bon (1996) divided the genus based on shape of spore and germ-pore, and structure of annulus and stipe covering (Vellinga *et al.* 2003). The sections identified were: *Macrolepiota*, *Macrosporae* and *Laevistipedes* (Pázmány) Bon. Section *Macrosporae* was further categorized into two subsections, *Excoriatae* Bon and *Microsquamatae*. Section *Laevistipedes* is characterized by species having spores without a germ-pore and a hyaline cap. Vellinga (2001d) identified two groups within the genus without designating any infrageneric ranks or names. One group was characterized by glabrous stipe, relatively small spores without a hyaline cap covering the germ-pore, and pileal surface with tightly arranged narrowly clavate elements. The other group had a squamulose/granulose stipe, spores with germ-pore cap, and with a more or less loosely composed trichodermial pileal covering with cylindrical terminal elements. Classifications by both Bon (1996) and Vellinga (2001d) place *Macrolepiota procera* and *M. rachodes* in different divisions while Singer's (1986) classification accommodates the two species under the same section (Vellinga *et al.* 2003). Earlier molecular analyses (Johnson 1999; Vellinga *et al.* 2003) supported the former placement. Subsequent molecular studies (Vellinga 2004a) however, suggested a restricted concept of *Macrolepiota*

where the genus seems better limited to the sections *Macrolepiota* and *Macrosporae*, after excluding species like *M. rachodes*.

2.3.7.2 Phylogeny

Preliminary investigations by Johnson & Vilgalys (1998) & Johnson (1999) pointed to the polyphyletic nature of *Macrolepiota*. Studies on the phylogeny and taxonomy of *Macrolepiota* by Vellinga *et al.* (2003) showed that the traditional concept of the genus (Singer 1986) cannot be maintained as some *Macrolepiota* species settle in clades along with the green-spored *Chlorophyllum*. The ITS and ITS-LSU based phylogenetic analyses (Vellinga *et al.* 2003) revealed two distinct lineages within *Macrolepiota*, that do not form a monophyletic clade. Further molecular studies by Vellinga (2004a) conclude that *Macrolepiota* and *Chlorophyllum* separately are monophyletic but not together. The status of a distinct genus for the volvate taxa that resemble *Macrolepiota* in most respects and accepted as *Volvolepiota* by Singer now seems untenable as they form a separate clade within *Macrolepiota sensu stricto* or at the base of the *Macrolepiota* clade (Vellinga *et al.* 2003; Vellinga & Yang 2003, Vellinga 2004). The *Volvolepiota*, therefore, is to be considered a synonym of *Macrolepiota* (Vellinga & Yang 2003; Vellinga 2004).

2.4 Biology and Ecology

Lepiotaceous fungi adopt a strictly saprobic mode of nutrition. They are what Vellinga (2004b) called 'substrate generalists', but the majority of

taxa are known to grow on leaf litter in forest floor and on humus rich soil (e.g. *Lepiota subincarnata*, *L. viriditincta*, *L. citrophylla*). Several species have been collected from dead and decomposing wood (e.g. *Leucocoprinus cepaestipes*, *L. birnbaumii*), on dung (e.g. *Leucocoprinus bresadolae* (Schulzer) Moser, *L. birnbaumii*) and compost (*Macrolepiota excoriata*, *M. rhacodes*). Lepiotaceous species that inhabit saw dust and wood chips have been reported (Babos 1980, 1981; Hemmes & Desjardin 2002). Shaded places underneath shrubs and trees are the preferred places of growth (Vellinga 2004b) while taxa like *Chlorophyllum*, *Clarkeinda*, some *Leucoagaricus* species (e.g. *L. leucothites*) and many species of *Macrolepiota* (e.g. *M. dolichaula*) are frequently found in open habitats like lawns, grasslands and road sides.

A saprotrophic life-strategy, combined with the capability to degrade lignin and cellulose, helps them to function as efficient litter decomposers. Agerer & Iosifidou (2004) discussed the role of rhizomorphs in improved colonization and substrate utilization in agarics. Rhizomorphs, present in many species of *Lepiota*, *Leucoagaricus*, *Leucocoprinus* and *Macrolepiota*, enhance utilization of the heterogeneously distributed substrates.

Mycorrhizal association for a few species like *Lepiota luteophylla* Sundberg (Sundberg 1971a), *Lepiota subgracilis* Kühner, *Macrolepiota procera, and M. rachodes* has been attributed (Guzmán & Guzmán-Dávalos 1992) because of their regular fruiting around specific trees like *Cupressus macrocarpa*. Singer (1986) did not accept mycorrhizal status for any

Macrolepiota species. Dörfelt (1982) recorded his *Lepiota bettinae* Dörfelt collections as growing on roots of the fern *Phlebodium aureum*. Vellinga *et al.* (1998) synonymized *L. bettinae* with *L. rubella* Bresadola, a terrestrial species growing among grasses and ferns. Hence, in spite of such occasional claims, solid evidences are lacking for lepiotaceous fungi to be categorized as mycorrhizal.

Symbiotic interactions with leaf cutter ants (*Attinae*: *Formicidae*) have been reported in a few lepiotaceous species from the neo-tropics (Johnson & Vilgalys 1998; Vellinga 2001c). This association has long been a subject of interest for mycologists, entomologists and evolutionary biologists. *Leucocoprinus gongylophorus* (Møller) Heim is a well-known lepiotaceous ant-mutualist, observed to produce special hyphal structures called gongylides (Kost 2004) that store nutrients for their insect associates. Mueller (2002) assigns the attine associates provisionally to either the genus *Leucoagaricus* or *Leucocoprinus* indicating an uncertain taxonomic position at the same time averring that all those taxa clearly belong to the tribe *Leucocoprineae*. The ants that cultivate and feed on mycelial colonies of these fungi in turn effect their dispersal by transferring the cultivars between ant nests (Mueller *et al.* 1998). These ant-fungus associations are considered as highly integrated units where partners are mutually benefited by nutritional, physiological and antibiotic co-dependencies (Mueller 2002).

Lepiotaceous fungi are known to fruit after rain and thunderstorms at the end of summer and during autumn showers in temperate Europe

(Vellinga 2004b). Studies that outline the fruiting behavior of tropical fungi in low-land forests of Costa Rica (Kost 2004) revealed that fruit bodies of the genus *Leucocoprinus* were the first to appear immediately after heavy rain falls while species with larger basidiomes like that of *Lepiota* and *Macrolepiota* needed a period of six to 14 days of rainfall preceded by a day of high precipitation. Most temperate taxa grow gregariously producing relatively high number of fruit bodies with regularity at the same location every year, which is in contrast with that of tropical taxa where fruiting is mostly solitary (Vellinga 2004b) and highly irregular. *Chlorophyllum molybdites* can grow and fruit as fairy rings in tropical climates (Vellinga 2001e; Hemmes & Desjardin 2002).

An excellent comprehensive review on the state of knowledge of the ecology of lepiotaceous fungi has been provided by Vellinga (2004b).

2.5 Economic Importance

Apart from their ecological role as efficient litter decomposers, the importance of lepiotaceous fungi as powerful sources of bioactive compounds is presently gaining world-wide recognition. A number of compounds showing medicinal properties have been isolated from representatives of the group along with a variety of other active principles. Didukh *et al.* (2003) listed 26 lepiotaceous species (*Chlorophyllum molybdites*, *Cystolepiota seminuda*, five *Leucocoprinus* species, four *Leucoagaricus* species, three *Macrolepiota* species and 12 *Lepiota* species)

with proven anticancerous, antibiotic, nutrient supplementary, and immunotherapeutic properties.

Many mushrooms are known to adsorb and concentrate heavy metals from their substrata, and such a potential in species like *Macrolepiota procera* and *M. rachodes* has been recognized (Vellinga 2004b; Gadd 2007). This ability to accummulate heavy metals and radionuclides could possibly be exploited in bioremediation of polluted environments. The temperature sensitive species of *Leucoagaricus* and *Leucocoprinus* are suggested as good indicators of climate change (Vellinga 2004b).

Approximately 40 species of lepiotaceous species are considered as edibles (Guzmán & Guzmán-Dávalos 1992). The edibility/toxicity of majority of the species remains untested. Of the known edible species, the large and fleshy *Macrolepiota* species are the most popular. Singer (1986) notes that 'all the species of sect. *Macrolepiota* (*Macrolepiota*) tested thus far have been found to be edible' and Guzmán & Guzmán-Dávalos (1992) mention that species 'such as *M. procera*, are highly priced in European, Asiatic and African markets'. Some species belonging to the genus *Leucoagaricus*, such as *Leucoagaricus holosericeus* (Fries) Moser and *L. leucothites* are considered palatable (Guzmán & Guzmán-Dávalos 1992; Wasser 1993). Taxa like *Macrolepiota procera* and *Leucoagaricus leucothites* are now commercially cultivated. Smith & Weber (1982) found the cooked taste of *Leucocoprinus breviramus* Smith & Weber to be very good, but subsequent reports to prove its edibility are not available. In the genus *Leucocoprinus*,

except *Leucocoprinus cepaestipes* and *L. gongylophorus* with doubtful edibility (see Guzmán & Guzmán-Dávalos 1992) and *L. meleagris*, none of the other members seem fit for human consumption. A few species of *Lepiota* are sometimes consumed (e.g. *Lepiota clypeolaria*).

Of the lepiotaceous taxa tested for their toxicity/edibility, many proved to be toxic. *Chlorophyllum molybdites* is a common and well-known toxic species which causes the majority of mushroom poisonings (Singer 1986; Sundberg 1971b; Guzmán & Guzmán-Dávalos 1992). *Lepiota xanthophylla*, *L. josserandii* Bon & Boiffard, and *L. brunneoincarnata* Chodat & Martin are examples of highly toxic species that cause *Amanita phalloides*-type poisoning (Besl *et al.* 1984; Haines *et al.* 1985; Schulz-Weddigen 1986). Some of the other common poisonous taxa are *Lepiota lilacea*, *Leucocoprinus badhamii*, *L. birnbaumii*, and *Macrolepiota venenata* Bon.

Damage to cultivated lawns and grasslands are known to be caused by the growth of *Chlorophyllum molybdites*.

2.6 Geographic Distribution

Checklists (Guzmán & Guzmán-Dávalos 1992; Vellinga 2006) of the lepiotaceous fungi are available that serve as exclusive indices to all names published so far, with literature references. These checklists give a bird's eye view of the extent of geographic distribution. The group as a whole has a cosmopolitan distribution and is mainly centered in the tropics and subtropics as already observed by many authors (e.g. Singer 1986; Guzmán &

Guzmán-Dávalos 1992; Johnson & Vilgalys 1998). Ironically, a huge lacuna in distribution-data from the tropics still exists while temperate areas like Europe are comparatively well-studied (Vellinga 2004b). A few species have been recorded from arctic and alpine habitats (Kühner 1983; Peintner & Horak 1999).

Exhaustive contributions like those of Candusso & Lanzoni (1990), Bon (1996) and Vellinga (2001g) serve as excellent regional monographs although the group lacks a world monograph. Candusso & Lanzoni (1990) and Bon (1996) provided a detailed account of all the known taxa distributed in Europe. Significant information on the group occurring in The Netherlands has been given by Vellinga (2001g). Wasser (1993) thoroughly studied the tribe *Leucocoprineae* of the Commonwealth of Independent States (CIS) and Baltic States (of the former Soviet Union). Other major accounts on the lepiotaceous fungi are from Africa (Beeli 1936; Pegler 1972; 1977), the Lesser Antilles (Pegler 1983), Australia (Aberdeen 1962), Germany (Enderle & Krieglsteiner 1989), Sri Lanka (Pegler 1986), Switzerland (Britenbach & Kranzlin 1995), USA (Kauffman 1924; Smith 1954, 1965), and Trinidad (Dennis 1952).

In addition to the major works listed above, several sporadic documentations are available, covering a wide range of geographical areas. A few noteworthy regional records are: Africa (Pearson 1950; Heim 1967, 1969, Heinemann 1968, 1969, 1973, 1977a 1979, 1980; Pegler 1969; Reid & Eicker 1993a, 1993b), Argentina (Singer & Digilio 1952,), Australia (Singer

1969; Horak 1980b; May & Wood 1997; Vellinga 2003c), Bolivia (Reid *et al.* 1981), Britain (Rea 1922; Reid 1958, 1989, 1990, 1995, 1997; Pearson 1952; Pegler 1963), Cameroon (Mossebo *et al.* 2000), China (Vellinga & Yang 2003; Wang & Yang 2005; Ge & Yang 2006), Colombia (Franco-Molano 1999), Cuba (Pegler 1988), Denmark (Lange 1915; Lange, C. 1995; Möller 1958), whole Europe (Bon & Boiffard 1972, Bon 1976; Knudsen 1980), France (Locquin 1945a, 1951, 1952; Bon & Boiffard 1974; Bodin & Priou 1994), Germany (Krieglsteiner 1981 1982; Dörfelt 1982), Hawaii (Hemmes & Desjardin 2002), Hungary (Babos 1958, 1961, 1969, 1974, 1979, 1980, 1981, 1985, 1995), Israel (Didukh *et al.* 2003), Italy (Migliozzi *et al.* 1989a, 1989b; Migliozzi & Perrone 1982; Migliozzi & Coccia 1982; Contu 1991; Bizzi & Migliozzi 1994; Bizzi 1997), Japan (Imai 1941), Latvia (Urbonas *et al.* 1986), Mexico (Cifuentes & Guzmán 1981; Guzmán-Dávalos & Guzmán 1982; Guzmán & Guzmán-Dávalos 1992; Montoya & Bandala 2005), The Netherlands (Kelderman 1988a, 1988b, 1988c, 1989, 1991a, 1991b, 1992, 1994; Vellinga & Huijser 1993; De Kok & Vellinga 1998), New Zealand (Horak 1980a, 1980b), Norway (Bon 1985), Panama (Akers & Ovrebo 2005), Papua-New Guinea (Hongo 1976; Horak 1980b), Romania (Pázmány 1985), Russia (Malysheva 2005), Spain (Moreno *et al.* 1995; Esteve-Raventós & Altés 1990; Esteve-Raventós & Calonge 1996), Sri Lanka (Berkeley & Broome 1870; Petch 1908, 1910), Tanzania (Pegler 1975), USA (Kauffman 1924; Murrill 1911, 1912, 1942, 1943, 1944, 1946, 1949, 1951; Zeller 1934; Smith & Rea 1944; Smith & Sundberg 1979;

Burlingham 1945; Sundberg 1971a, 1971b, 1976, 1989; Akers & Sundberg 1998, 2000; Akers *et al.* 2000), and Venezuela (Dennis 1961).

About 104 lepiotaceous taxa seem to have been recorded from India till date. Of these, Manjula (1983) had listed a total of 72 taxa, based on reports from Andaman Islands and from the States of Andhra Pradesh, Assam, Gujarat, Himachal Pradesh, Kerala, Maharashtra, Sikkim, Punjab, Tamil Nadu, Uttar Pradesh and West Bengal. The listed taxa belonged to the genera *Chlorolepiota*, *Chlorophyllum*, *Clarkeinda*, *Lepiota*, *Leucoagaricus*, *Leucocoprinus*, *Macrolepiota* and *Volvolepiota*. Natarajan *et al.* (2005) listed another 30 taxa based on reports from India that appeared between 1984 and 2002. These taxa belonged to *Cystolepiota*, *Lepiota*, *Leucoagaricus* and *Leucocoprinus*. Other latest reports are by Vrinda *et al.* (2003) and Kumar & Manimohan (2004).

Interestingly, from Kerala, only 20 taxa of lepiotaceous fungi have been reported so far (see table 2.).

All the morphological, ultrastructural and molecular studies carried out so far on the lepiotaceous fungi helped to develop a taxonomic frame work, elucidating the diversity, relationships and status of the group to a limited extent. Further studies are warranted towards a better understanding of the group with regard to its distribution and phylogenetics. An integrated approach, combining morphology, cytogenetics, ultrastructure and molecular data alone can provide definite solutions to complex taxonomic enigmas prevailing in the group. The characters of cystidia and pileal covering play a

very important role in the taxonomic delimitation of lepiotaceous fungi, and their significance as strong morphological markers in distinguishing genera and species of the homobasidiomycetes has been well-recognized (Lentz 1971; Setliff 1979). Integrated light and electron microscopic studies elucidating the fine structure of the cystidia and pileal covering may prove taxonomically informative. However, prime importance should be given to intensive exploration of habitats of lepiotaceous fungi to reveal the full diversity and greater ecological roles played by these fungi.

Table 1. An outline of major classification systems proposed for lepiotaceous fungi -

Kuhner (1936)	Locquin (1945)	Singer (1986)	Bon (1996)
Gen ***Lepiota***	Gen ***Lepiota***	**Tribe *Lepioteae***	**Tribe *Lepioteae***
Sec *Echinatae*	S.gen *Echinoderma*	Gen ***Lepiota***	Gen ***Melanophyllum***
Sec *Cristatae*	S.gen *Lepiotula*	Sec *Echinatae*	Gen ***Pseudobaeospora***
Sec *Integrellae*	S.gen *Integrella*	Sec *Amyloideae*	Gen ***Lepiota***
Sec *Clypeolariae*	S.gen *Eulepiota*	Sec *Cristatae*	S.gen *Lepiota*
Sec *Stenosporae*	S.gen *Lepiotella*	Sec *Stenosporae*	Sec *Lepiota*
Sec *Ovisporae*	S.gen *Micacystis*	Sec *Lepiota*	S.sec *Latisporinae*
Sec *Annulosae*	S.gen *Sericella*	Sec *Ovisporae*	S.sec *Fusisporinae*
Sec *Lepiotellae*	S.gen *Pilosella*	Sec *Anomalae*	Sec *Helveolae*
Sec *Micaceae*	Gen ***Leucocoprinus***	Sec *Amylosporae*	S.sec *Helveolinae*
Sec *Sericellae*	S.gen *Leucoagaricus*	Gen ***Chamaemyces***	S.sec Parvannulatae
Sec *Pilosellae*	S.gen *Euleucocoprinus*	Gen ***Cystolepiota***	Sec *Fuscovinaceae*
Sec *Procerae*	S.gen *Hiatula*	Sec *Cystolepiota*	Sec *Felinae*
Sec *Striatae*	S.gen *Leucobolbitius*	Sec *Pseudoamyloideae*	S.sec *Felininae*
Sec *Granulosae*	Gen ***Cystoderma***	Gen ***Smithiomyces***	S.sec *Brunneoincarnatae*
Gen ***Limacella***		Gen ***Hiatulopsis***	S.sec *Paralilaceae*
		Gen ***Janauaria***	S.sec *Parvannulatae*
		Tribe *Leucocoprineae*	S.gen *Lepiotula*
		Gen ***Sericeomyces***	Sec *Cristatae*
		Gen ***Leucoagaricus***	Sec *Stenosporae*
		Sec *Annulati*	S.sec *Stenosporae*
		Sec *Rubrotincti*	S.gen *Paralepiotula*
		Sec *Sculpturati*	Sec *Lilaceae*
		Sec *Leucoagaricus*	Sec *Integrellae*
		Sec *Piloselli*	Gen ***Chamaemyces***
		Sec *Sphaerocystophori*	Gen ***Cystolepiota***
		Gen ***Macrolepiota***	Sec *Cystolepiota*
		Sec *Macrolepiota*	S.sec *Seminudae*
		Sec *Macrosporae*	S.sec *Floccosinae*
		Gen ***Chlorophyllum***	S.sec *Cystidiosinae*
		Gen ***Clarkeinda***	Sec *Pseudoamyloideae*
		Gen ***Volvolepiota***	Gen ***Pulverolepiota***
		Gen ***Leucocoprinus***	Gen ***Echinoderma***
		Tribe *Cystodermatae*	**Tribe *Leucocoprineae***
		Gen ***Cystoderma***	Gen ***Chlorophyllum***
		Gen ***Ripartitella***	Gen ***Leucoagaricus***
		Gen ***Phaeolepiota***	Sec *Leucoagaricus*
		Gen ***Dissoderma***	S.sec *Leucoagaricus*
		Gen ***Squamanita***	S.sec *Melanotrichi*
		Gen ***Pseudobaeospora***	Sec *Annulati*
		Gen ***Horakia***	S.sec *Rubescentes*
			S.sec *Annulosi*
			Sec *Piloselli*
			S.sec *Piloselli*
			S.sec *Pilatiani*
			Sec *Rubrotincti*
			S.sec *Trichodermi*
			S.sec *Rubrotincti*
			Gen ***Leucocoprinus***
			Sec *Cepaestipides*
			Sec *Denudati*

Gen ***Macrolepiota***
Sec Macrolepiota
Sec *Macrosporae*
S.sec *Excoriatae*
S.sec *Microsquamatae*
Sec *Laevistipedes*
Gen ***Sericeomyces***

Gen – Genus, S.gen – Subgenus, Sec – Section, S.sec – Subsection

Table 2. Lepiotaceous taxa previously reported from Kerala

Taxa	Reports
1.) *Chlorophyllum cochinence* Sathe & Sasangan	Sathe & Sasangan (1977)
2.) *Chlorophyllum molybdites* (Meyer) Massee	Florence (2004)
3.) *Clarkeinda trachodes* (Berkeley) Singer	Leelavathy *et al.* (1981)
4.) *Cystolepiota hemisclera* (Berkeley & Curtis) Pegler	Vrinda *et al.* (1997)
5.) *Lepiota guatopoensis* Dennis	Vrinda *et al.* (2001)
6.) *Lepiota pyrrhaes* (Bereley & Broome) Saccardo	Vrinda *et al.* (1999)
7.) *Lepiota viriditincta* (Berkeley & Broome) Saccardo	Manimohan *et al.* (1988)
8.) *Leucoagaricus hortensis* (Murrill) Pegler (= *Chlorophyllum hortense* sensu Vellinga)	Vrinda *et al.* (1999)
9.) *Leucoagaricus quilonensis* Sathe & Daniel	Sathe & Daniel (1980)
10.) *Leucocoprinus biornatus* (Berkeley & Broome) Locquin	Vrinda *et al.* (2003)
11.) *Leucocoprinus birnbaumii* (Corda) Singer	"
12.) *Leucocoprinus brebissoni* (Godey) Locquin	"
13.) *Leucocoprinus bresadolae* (Schulzer) Moser	"
14.) *Leucocoprinus cepaestipes* (Sowerby) Patouillard	"
15.) *Leucocoprinus fragilissimis* (Berkeley & Curtis) Patouillard	"
16.) *Leucocoprinus meleagris* ([Sowerby] Gray) Locquin	"
17.) *Leucocoprinus squamulosus* (Montagne) Pegler	"
18.) *Leucocoprinus venezuelanus* Dennis	"
19.) *Leucocoprinus zeylanicus* (Berkeley) Boedjin	Vrinda *et al.* (1997, 2003)
20.) *Leucocoprinus lacrymans* T. K. A. Kumar & Manimohan	Kumar & Manimohan (2004) #

- reported during the course of this study

A FLORISTIC STUDY OF THE LEPIOTACEOUS FUNGI OF KERALA AND SOME TAXONOMIC OBSERVATIONS ON THE GROUP

Thesis submitted to the University of Calicut
in partial fulfilment of the requirements for the Degree of
DOCTOR OF PHILOSOPHY
in Botany

By

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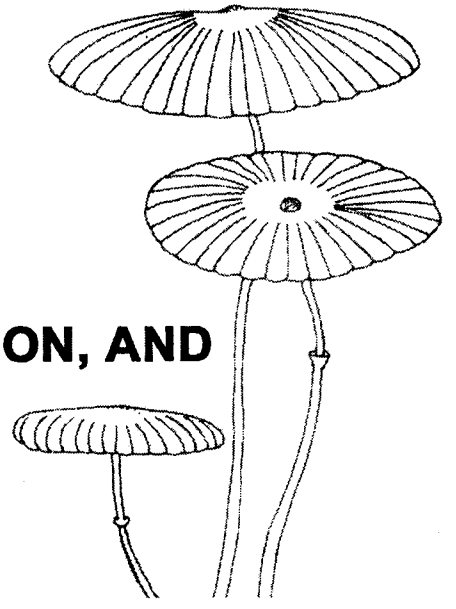
2007

Chapter 3

PHYSIOGRAPHY, VEGETATION, AND CLIMATE OF KERALA



Chapter 3

PHYSIOGRAPHY, VEGETATION, AND CLIMATE OF KERALA

3.1 Physiography

The State of Kerala is at the south west edge of peninsular India, nestled between the Arabian Sea to its west and the Western Ghats to the east. It has a total geographic area of 38,863 sq. km and is situated between 8° 18' and 12° 48' north latitudes and between 74° 52' and 77° 21' east longitudes. The geographic area can be divided into three main zones: 1) the lowland coastal areas comprising river deltas, backwaters, estuaries and the shores of the Arabian Sea. This coastal line stretches to about 580 km in length. 2) Immediately east of the coastal belt are the midland plains composing central Kerala. This zone is chiefly constituted by undulating hills and valleys. 3) The Western Ghats mountain ranges make up the highlands spanning on the eastern side, rising on average to 1500-2680 m above sea level. These mountain ranges teem with diverse life forms and are abode to many endemic plant and animal species. The 44 rivers of Kerala (41 west-flowing and 3 east-flowing) originate from these mountains. The significant geological formations in Kerala are pre-Cambrian and Pleistocene.

3.2 Vegetation

With a forest cover of about 10, 336 sq. km, the state of Kerala possesses extensive tracts of tropical wet evergreen forests, tropical semi-evergreen forests and moist deciduous forests. Dry deciduous forests,

although rare are found as patches in Anamalai and Wayanad plateaus. Specialized grass lands are found in Anamalai region above 1500 m. Montane subtropical and temperate (shola) forests are found at higher elevations. The Munnar area of Idukki district which is in the Nilgiri Biosphere has such temperate forests. Wetland mangrove forests are distributed throughout the State, except in Idukki, Pathanamthitta, Palakkad and Wayanad districts. Some prominent plant species occurring in the forests of Kerala are: *Bambusa arundinacea*, *Dalbergia latifolia*, *Dendrocalamus strictus*, *Dipterocarpus indicus*, *Eurya japonica*, *Gardenia obtusa*, *Michelia nilagirica*, *Sterculia elata*, *Tectona grandis*, and *Toona ciliata*.

A high level of endemism is found in the angiosperm flora of Kerala. There are about 1272 endemic species occurring in Kerala, which is 33.5% of its angiosperm flora and about 22.6 % of the total angiosperm flora endemic to India. The peninsular Indian endemic flora is of Gondwanaland origin and the endemic flora of Kerala is mainly palaeotropic in composition. As per information given by the Kerala Forest Research Institute (http://www. Keralaforest.org/html/flora/endemic.htm), the characteristic endemic flora of Kerala and Sri Lanka show similarities indicating their development from a common stock, but isolated due to temporal or geographical barriers. A few of the angiosperm taxa endemic to Kerala are: *Baeolepis, Chandrasekharania, Haplothismia, Kanjarum*, *Pseudoglochidion, Silentvalleya, Utleria* and *Meteoromyrtus.*

Twelve Wild life Sanctuaries (Aralem, Chenduruny, Chimmony, Chinnar, Idukki, Neyyar, Parambikulam, Peechi-Vazhani, Peppara, Periyar, Thattekkad, , Wayanad,), two National Parks (Eravikulam, Silent Valley) and a Biosphere Reserve (Nilgiri) have been recognized inside the State.

3.3 Climate

The humid tropical area has a unique rainfall and temperature pattern that influence its vegetation. Kerala is classified as a Tropical Wet climatic region. The State receives a mean rainfall of 3107 mm in 120-140 rainy days annually. The rainfalls result from two monsoons, the north east and the south west. South west monsoon that begins by early June and extending up to September, brings in the heaviest rainfall and contributes to about 60 % of the total rainfall per year. A relatively lesser precipitation rate is characteristic of the north east monsoon, happening during the months of October to December. Occasional off-season rainfalls are also received. Dry weather conditions prevail during the summer season that starts from the middle of December and gradually ends by early June. Temperature varies from a daily mean minimum of 19.8 °C to a mean maximum of 36.7 °C. Regions of high elevations like the Munnar area of Idukki district experience an almost temperate climate with temperature rarely dipping to about 0° C. during the months of November to January. (Information sources – http://www. Keralaforest.org; http://en.wikipedia.org/wiki/Kerala#Geography; Negi 1994).

3.4 The Calicut University campus and adjoining regions

The most thoroughly explored region in this study is the Calicut University campus and its adjoining regions. The Calicut University campus at Thenjippalam in Malappuram district is in the central western part of the upper half of Kerala. It lies at an altitude range of 40-50 m, in the north-south direction with its long axis parallel to the western sea board. With a total area of about 220 hectares, the undulating terrain is characterized by stretches of laterite and intermittent zones of gravel and red loamy soil. The vegetation is basically a secondary scrub jungle mixed with large isolated patches of grass intermixed with groves of *Acacia auriculiformis*, *Anacardium occidentale*, *Mangifera indica* and a few other trees. Lowland areas surround the campus on all sides. The western side gradually slides into deep valleys beyond which stretches hill ranges and valleys bordering the sea, 3 km west of the campus. Adjoining areas too have a similar terrain.

Other major collection areas are indicated in the outline map of Kerala along with photographs of some of them.

MAP OF KERALA SHOWING COLLECTION LOCALITIES

Wayanad

Thenmala

Palode

Muthanga

Peruvannamuzhy

Kottathara

70.E

Nilambur

Calicut University campus

Madupetty

Munnar

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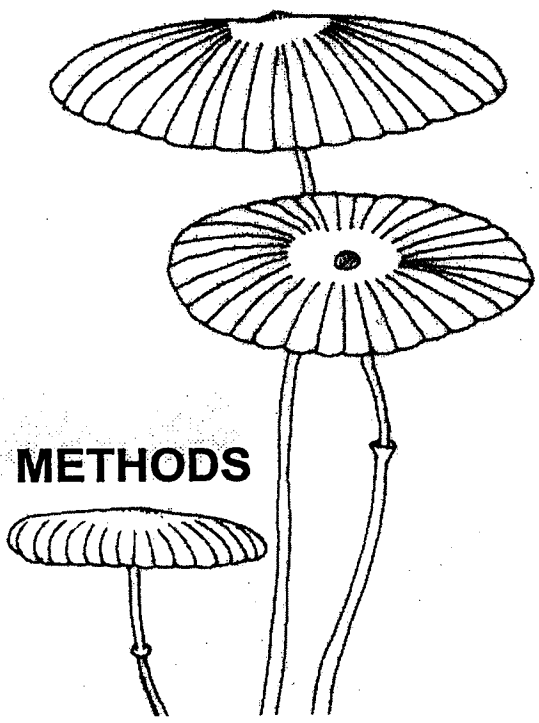
Chapter 4



MATERIALS AND METHODS

Chapter 4
MATERIALS AND METHODS

4.1 FLORISTIC STUDY

4.1.1 Field study and research material

Fresh basidiomata were collected during the south-west (June - September) and north-east (October - November) monsoon seasons, from different localities of Kerala state, for a continuous period of three-and-a-half years (June 2003 - December 2006). Forests, grasslands, roadsides, gardens, parks, and other open areas were surveyed alike. The most intensive field work was done in the northern parts of Kerala, mainly focusing on the floristically rich areas of Calicut, Malappuram and Wayanad districts. An exhaustive floristic study of the group in and around the University of Calicut campus (Malappuram District), which has an area of about 220 hectares, was carried out. Dried herbarium specimens of a few species deposited at the mycological herbarium of the Microbiology division, Tropical Botanic Garden and Research Institute, Kerala (TBGT) were examined.

4.1.2 Recording of macroscopic characters

Basidiomata were photographically recorded *in situ*, using Nikon CoolPix 5000 and Canon Power Shot A610 digital cameras. Basidiomata were carefully picked, field-notes were prepared indicating their habit, habitat, collection date, range of variation in size, shape, colour and other salient features and wrapped in paper and brought to the laboratory for

further study and subsequent preservation. Thorough macroscopic observation was done using a Labomed CZM4 stereo microscope and characters were recorded in a systematic manner after examining a number of fresh specimens at different developmental stages. Colour reactions of basidiomata on treatment with ammonia, potassium hydroxide, nitric acid and aniline were tested. Spore-print colour was noted from spore-prints obtained on white paper, from mature pilei removed from their stipe. All material, after detailed macroscopic study were prepared for preservation by drying in a hot-air oven at 40-50°C overnight or by refrigerating till complete dehydration was achieved. The dried specimens with proper labelling were put in paper packets and stored in a refrigerator for preservation. Kornerup & Wanscher (1978) is followed for the colour codes used in species descriptions.

4.1.3 Study of microscopic characters

Both fresh as well as dried herbarium material were used for the study, but parts of the fresh specimens before drying were mostly preferred. Thin free-hand sections from different parts of the basidiomata were cut under a stereo microscope using a razor blade, and stained using a mixture of 1% aqueous solutions of phloxine and Congo red and 3% aqueous KOH. The sections mounted on glass slides were covered with cover slips and further washed with 3% aqueous KOH to remove excess stain. Melzer's reagent was used to determine the amyloidy/ dextrinoidy/ inamyloidy of the spores and tissues, and the metachromatic reaction of spores were checked

with 1% aqueous cresyl blue. All microscopic examinations were done employing either an Olympus CX21 or a Reichert Microstar IV trinocular compound microscope both having planar oil-immersion objectives. The anatomical characters observed were recorded as line drawings (with 100× oil immersion objective for spores, basidia and cystidia and 40× objective for pileal and stipe cuticle elements), using a mirror-type camera-lucida attached to the microscope.

Spore-dimensions were measured and shapes were determined from basidiospores taken either from spore-prints or in the absence of spore-prints, from the hymenium. The spore measurements for each species were taken using an eyepiece micrometer, from 20 mature randomly selected spores. While recording spore dimensions, the lengths were given first followed by breadth measurements. The arithmetic mean of length and breadth was calculated using the formula 'Mm = Mo / n', where 'Mo' represents observation value and 'n' is the number of observations. The root mean square deviation was calculated using the formula, δ = square root of $\sum (Mm - Mo)^2$, divided by n − 1. The ratio of spore length to its width (Q) was calculated for 20 spores each and the average of these values was calculated and recorded as Qm.

All measurements were made without considering the hilar appendix and the lens-cap-like exudate found covering the germ pore of some members of the tribe *Leucocoprineae* Singer. The presence or absence of

germ pore, its width, and the spore wall-thickness were noted. All spore measurements were rounded to the nearest half of a micrometer.

Basidial and cystidial shapes were noted and length ranges were recorded from the smallest and largest cells in each collection examined, excluding the sterigmata and encrustations if any, on the surface of these cells. The range of basidial, cystidial and hyphal width were measured at the widest point of individual cells. The contents, pigmentation and exudation of these cells were observed on unstained material mounted in pure water. Occurrence of pseudoparaphyses (pavement cells) in the hymenium and the nature of subhymenium were also studied.

Structure of the pileal covering was studied from radial sections taken consistently from the margin as well as from the disc of the pileus. The hyphal arrangement and composition on the pileus was observed and shape and dimensions of the pileal elements were determined. Similarly, the arrangement of hyphae on the stipe was also studied. Sections mounted on pure water were used to identify the pigmentation type and colour of the pileal and stipe hyphal cells.

Collections made and examined in the course of this study are preserved at the Mycology Laboratory of Botany Department, University of Calicut.

4.1.4 Classification system and taxonomic concepts followed

Taxa belonging to the two tribes *Lepioteae* & *Leucocoprineae sensu* Singer (1986), of the family *Agaricaceae* are considered in this study as comprising the group called lepiotaceous fungi. The tribe *Cystodermatae* and genus *Sericeomyces* is excluded from the group following evidences against their phylogenetic affinities with lepiotaceous fungi, based on recent molecular studies (Johnson & Vilgalys 1998; Moncalvo *et al.* 2002; Vellinga 2004). Generic and infrageneric concepts followed are basically that of Singer (1986). All taxa with well-developed pseudoparaphyses in the hymenium are placed in the genus *Leucocoprinus* Patouillard, including species that turn greenish on exposure to ammonia fumes, which Singer (1986) treated under *Leucoagaricus*. The genus *Chlorophyllum* is treated in the sense of Vellinga (2002), incorporating species with green- as well as pale-coloured spore print. This amended concept of *Chlorophyllum* is followed because it is supported by both morphological and molecular data. A morphological species concept (see Kuyper 1988: 31) is adopted throughout the work. Characters with a high constancy, such as colour of basidiomata; shape and size of spores; presence, type and width of germ-pore; size and shape of cheilocystidia; and presence/absence of pleurocystidia, were primarily considered for species delimitation. Infraspecific variability categorized in this work as variety was recognized after studying adequate number of specimens.

4.1.5 Standard works referred

For distribution records and data on all published names of lepiotaceous species, including their synonyms, *nomen nuda*, excluded species, author names and literature citations, 'A checklist of lepiotaceous fungi' (Guzmán & Guzmán-Davalos 1992) and 'Nomenclatural overview of Lepiotaceous fungi. ver. 2.1.' (Vellinga 2006) are followed.

For descriptive terminology of macro and microcharacters, 'How to identify mushrooms to genus I: Macroscopic features' (Largent 1977) and 'Flora Agaricina Neerlandica, vol. 1' (Bas *et al.* 1988) are followed.

4.1.6 Major taxonomic treatises consulted

1. *Lepiota* s.l. Fungi Europaei 4. (Candusso & Lanzoni 1990)
2. Die Grosspilzflora von Europa. *Lepiotaceae*. (Bon 1996)
3. *Macrolepiota*, *Chlorophyllum*, *Leucocoprinus*, *Leucoagaricus*, *Lepiota*, *Cystolepiota*. (Vellinga 2001g).
4. A Preliminary Agaric Flora of East Africa. (Pegler 1977).
5. Agaric Flora of the Lesser Antilles. (Pegler 1983).
6. Agaric Flora of Sri Lanka. (Pegler 1986)

4.2 INTEGRATED LIGHT AND ELECTRON MICROSCOPIC STUDIES ON CHEILOCYSTIDIA AND PILEUS COVERING OF THREE LEPIOTACEOUS TAXA

Representative collections belonging to three lepiotaceous genera (*Chlorophyllum*, *Lepiota* and *Leucoagaricus*) were selected for a combined cellular and subcellular study of cystidial and pileal covering characters. For this investigation, basidiomata of *Chlorophyllum molybdites* (Meyer) Massee, and *Leucoagaricus leucothites* (Vittadini) Wasser were collected from the University of Minnesota campus and those of *Lepiota clypeolaria* (Bulliard) Kummer from the Cedar Creek Natural History Area, Minnesota, USA during September and October 2005. Electron microscopic procedures and tissue fixation and embedding protocols followed for light microscopy, were those optimized at the McLaughlin Lab, Department of Plant Biology, University of Minnesota, USA, where this part of the research was carried out.

4.2.1 Light microscopy

Slices of lamellae and wedge-shaped tissue-blocks, removed from the pileus of fresh basidiomata using a razor blade were fixed in 2 % (vol/vol) gluteraldehyde in 0.1 M sodium cacodylate buffer (pH 7.2) at room temperature in a straight-edge glass tube tightened with a cork, for 1 hour and rinsed in three changes of 0.1 M sodium cacodylate buffer for 15 minutes each. The samples were then washed three times in glass-distilled water for 10 minutes each and later covered with 25 % ethanol for two hours, followed by treatment in a graded acetone series as follows: 50 % ethanol

for 30 minutes, 75 % ethanol for 30 minutes, 95 % ethanol for 30 minutes, 100 % ethanol for one hour (100 % ethanol treatment was repeated seven times).The dehydrated samples were infiltrated with and embedded in glycol methacrylate (GMA) (Polysciences, Inc., Warrington, PA) prepared according to manufacturer's instructions, by incubating overnight in vacuum at 4°C.

Sample-embedded GMA blocks were sectioned using a Reichert-Jung ultramicrotome with a glass knife. Sections 2-3 µm thick were picked with a fine-tip forceps and transferred on to distilled water drops on precleaned glass slides and dried in a blast of air at room temperature. Dried sections adhered on to glass slides were stained using periodic acid-Schiff (PAS) reagent and toluidine blue solution in benzoate buffer, pH 4.4, following procedures of Feder and O'Brien (1968) and examined with a Zeiss light microscope.

4.2.2 Transmission electron microscopy

Samples with target cells, removed from the pileus of fresh basidiomata using a razor blade were fixed in 2 % (vol/vol) gluteraldehyde in 0.1 M sodium cacodylate buffer (pH 7.2) at room temperature in a straight-edge glass tube with a cork, for one hour and rinsed in three changes of 0.1 M sodium cacodylate buffer for 15 minutes each. The samples were then postfixed in 1 % (vol/vol) osmium tetroxide in the same buffer for four hours at room temperature, rinsed with glass-distilled water three times for 15 minutes each, and stained overnight with 0.5 % (vol/vol) aqueous uranyl

acetate at room temperature in the dark. After three 10-minute rinses in water, specimens were dehydrated in a graded acetone series (25 % for two hours, 50 %, 75 %, 95 % for 30 minutes each, and 100 % for one hour), and infiltrated with Quetol 651 resin (Ted Pella, Inc., Redding, California). Half of the samples were dish embedded (Mims *et al.* 2003) while the other half were flat embedded (following Kleven & McLaughlin 1989). Resin was polymerized at 74°C for 24–48 hours.

Blocks were sectioned on a Reichert-Jung ultramicrotome using a diamond knife. Thin (96–100 nm) sections were collected on Formvar-coated single-slot copper grids and were dried on carbon-coated Formvar bridges using the procedure of Rowley and Moran (1975). Sections were stained with 3% uranyl acetate followed by triple lead stain (Sato 1968), and examined with a Philips CM-12 transmission electron microscope operating at 60 kV.

A FLORISTIC STUDY OF THE LEPIOTACEOUS FUNGI OF KERALA AND SOME TAXONOMIC OBSERVATIONS ON THE GROUP

Thesis submitted to the University of Calicut
in partial fulfilment of the requirements for the Degree of
DOCTOR OF PHILOSOPHY
in Botany

By

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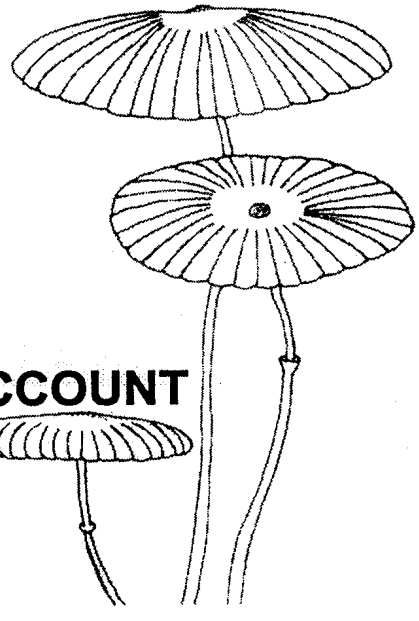
2007

Chapter 5



SYSTEMATIC ACCOUNT

Chapter 5
SYSTEMATIC ACCOUNT

5.1 KEY TO THE GENERA

1. Spores without a germ-pore, non-metachromatic in cresyl blue..... **2**
1. Spores with or without a germ-pore, metachromatic in cresyl blue **3**
2. Pileal covering made of ascending or erect, cylindrical to clavate elements or chains of ellipsoid to globose elements with intermediate cells ..... ***Lepiota***
2. Pileal covering made of loosely attached ellipsoid or globose elements without intermediate cells ..... ***Cystolepiota***
3. Basidiomata small to large; spore-print always white or yellowish white; clamp-connections very rare or almost absent..... **4**
3. Basidiomata always large; spore-print whitish or greenish; clamp-connections generally present or rarely absent..... **6**
4. Basidiomata mostly fragile; pileus radially striate; pseudoparaphyses well-developed and abundant in the hymenium ..... ***Leucocoprinus***
4. Basidiomata more or less sturdy; pileus usually non-striate; pseudoparaphyses absent ..... ***Leucoagaricus***
5. Volva present; average spore-size 6.5 × 4.4 µm ..... ***Clarkeinda***
5. Volva absent; average spore-size above 8 × 5.5 µm. **6**
6. Germ-pore covered by a hyaline cap; stipe covering a cutis highly disrupted by trichodermial patches of differentiated elements..... ..... ***Macrolepiota***
6. Germ-pore not covered by a hyaline cap; stipe covering a cutis .... ***Chlorophyllum***

5.1.1 *Lepiota* (Persoon) Gray

Agaricus section *Lepiota* Persoon in Tentamen dispositionis methodicae fungorum: 68. (1797)

Agaricus tribus *Lepiota* Persoon: Fries in Systema mycologicum 1: 19 (1821)

Lepiota (Persoon) Gray in Natural arrangement of British plants 1: 601 (1821)

- *Fusispora* Fayod in Annales des sciences naturelles, series VII, Botanique 9: 351 (1889)

- *Lepiotula* (Maire) Locquin ex Horak in Synopsis Generum Agaricalium: 337 (1968)

- *Echinoderma* (Locquin ex Bon) Bon in Documents mycologiques 21

(82): 61 (1991)

Basidiomata small to medium-sized; pileal surface covered with fibrillose squamules that become concentrated towards the disc giving an almost smooth to pruinose appearance or with scattered pyramidal squamules; lamellae free, thin, nearly always with a concolorous edge; stipe central, almost equal, with a slight expansion towards the base, smooth, fibrillose or with distinct squamules in broken girdles; annulus mostly fibrillose, rarely membranous, persistant or fugacious; spores small to large, cylindrical, ovoid, ellipsoid, lacrymoid, fusoid, or amygdaliform, some basally spurred, dextrinoid, non-metachromatic in cresyl blue, germ-pore absent, smooth, hyaline, slightly thick- to thick-walled; cheilocystidia present, rarely absent; pleurocystidia not present in Kerala species; lamellar trama regular to subregular; pileal covering variable, not of repent filamentous hyphae nor

entirely made up of globose elements; stipe covering almost similar to that of the pileus.

Type species: *Lepiota clypeolaria* (Bulliard) Kummer [= *L. colubrina* (Persoon) Gray]

5.1.1.1 KEY TO THE SECTIONS AND SPECIES OF *LEPIOTA* OF KERALA

1. Spores spurred ..... (Section *Stenosporae*) **5**
1. Spores not spurred, but ellipsoid, ovoid, oblong, amygdaliform, subcylindric, lacrymoid or fusoid **2**
2. Spores large and (sub) fusoid. ***Lepiota metulaespora*** (Section *Lepiota*)
2. Spores small to medium-sized and not fusoid **3**
3. Pileus covering with pyramidal squamules, composed of agglutinated chains of inflated, cylindrical or ellipsoid to globose terminal elements ... . (Section *Echinatae*) **7**
3. Pileus covering with ascending or erect clavate, cylindrical, fusoid, lageniform or ventricose terminal elements **4**
4. Clamp-connections present ..... (Section *Ovisporae*) **9**
4. Clamp-connections absent ..... (Section *Anomalae*) **19**
5. Pileal covering with olive brown squamules; spores 6.5-9 × 3-4 µm .... ***Lepiota griseovirens***
5. Pileal covering with brown or brownish orange squamules **6**
6. Spores 6-9.5 × 3-4 µm; elements of pileal covering, without encrusting pigments; ..... ***Lepiota erythrosticta***
6. Spores 9-12 × 3.5-4.5 µm; elements of pileal covering with encrusting pigments ..... ***Lepiota castanea***
7. Pileus light orange with brown squamules; lamellae light orange; context light orange; cheilocystidia and pleurocystidia absent; spores 4-6 × 2-3 µm ..... ***Lepiota pseudoasperula***

7. Pileus light brown, reddish brown or dark brown; lamellae white; context white to yellowish white; cheilocystidia present but pleurocystidia absent.....8

8. Cheilocystidia inflated clavate, sphaeropedunculate or pedicellate-ovoid; clamp-connections absent; spores 4.5-7 × 3-4 µm ..... ***Lepiota* species 3**

8. Cheilocystidia clavate, utriform, cylindrical, pyriform, ellipsoid or ovoid; clamp-connections present but rare; spores 4-6 × 3 µm..... ***Lepiota* species 5**

9. Pileal covering predominantly made of long fusoid, cylindrical or flexuose elements with obtuse or acuminate apex **10**

9. Pileal covering made of cylindrical, clavate or ellipsoid elements mostly with obtuse apex..... **14**

10. Lamellae and context white to yellowish white; spore lengths range from 4.5 to 7.5 µm **11**

10. Lamellae and context pastel yellow; spore lengths range from 6 to 9 µm **13**

11. Pileal surface orange white with cinnamon brown squamules; elements of pileal covering up to 300 µm long; spores 4.5-7.5 × 3-5 µm..... ***Lepiota subincarnata***

11. Pileal surface whitish or yellowish white with brown to reddish brown squamules; elements of pileal covering up to 187 µm long **12**

12. Pileus 19-27 mm diameter; stipe turning brownish orange on bruising; cheilocystidia mostly septate and occasionally with apical excrescences; spores 4.5-6 × 3-4.5 µm..... ***Lepiota* species 8**

12. Pileus 4-17 mm diameter; stipe not exhibiting colour change on bruising; cheilocystidia aseptate and without apical excrescences; spores 4.5-7 × 2.5-4 µm ..... ***Lepiota brevipes***

13. Pileal covering made of long fusoid or clavate elements intermixed with a layer of smaller, invariably clavate elements; cheilocystidia cylindrical, clavate or utriform; spores 6-8 × 3-4.5 µm ..... ***Lepiota xanthophylla***

13. Pileal covering made up entirely of cylindrical or fusoid elements; cheilocystidia cylindrical or clavate; spores 6-9 × 3-4.5 µm ..... ***Lepiota elaiophylla***

14. Basidiomata medium-sized; Pileus more than 40 mm diameter; annulus with a dark grey squamulose rim; spores 6-9 × 3-4 (5) µm, lacrymoid to subcylindric, with a strong suprahilar depression; clamp-connections abundant..... ***Lepiota ianthinosquamosa***

14. Basidiomata small; Pileus less than 25 mm diameter; annulus without a coloured rim; spores oblong, ellipsoid, subcylindrical or amygdaliform without any distinct suprahilar depression; clamp-connections rare **15**

15. Basidiomata turn bluish green on bruising; spores 7-10 × 4-5 µm..... ***Lepiota viriditincta***

15. Basidiomata do not turn bluish green on bruising **16**

16. Pileus striate; stipe covering a cutis of repent hyphae **17**

16. Pileus non-striate; stipe covering a disrupted cutis with ascending hyphal elements..... **18**

17. Pileus whitish with brownish grey to reddish brown squamules; lamellae white; spores 5-7 × 3.5-5 µm, oblong-ellipsoid to broadly ellipsoid; pileal elements without encrusting pigments..... ***Lepiota* species 1**

17. Pileus whitish with dark brown squamules; lamellae yellowish; spores 5.5-8 × 3.5-4.5 µm, amygdaliform; pileal elements with encrusting pigments ..... ***Lepiota* species 6**

18. Basidiomata dull white with reddish brown squamules; cheilocystidia cylindrico-clavate, clavate, broadly clavate, utriform or ventricose-rostrate; pileal elements with encrusting pigment; spores 5.5-10.5 × 3.5-4.5 µm..... ***Lepiota* species 4**

18. Basidiomata white; cheilocystidia clavate to cylindrico-clavate; pileal elements without encrusting pigment; spores 6-9.5 × 3.5-5 µm..... ***Lepiota* species 2**

19. Basidiomata turning greyish green on bruising; terminal elements of pileal covering with encrusting pigment; spores 5-7 × 3-4 µm .....

..... ***Lepiota* species 7**

19. Basidiomata not turning greyish green on bruising; terminal elements of pileal covering lacking encrusting pigment **20**

20. Pileus 17-25 mm diameter, white with brownish grey squamules; annulus fugacious; spores 5-8 × 3.5-5 µm, ellipsoid to oblong-ellipsoid .... ***Lepiota plumbicolor***

20. Pileus 9 mm diameter, dark grey; annulus persistant; spores 4.5-6 × 3.5-4.5 µm, subamygdaliform ..... ***Lepiota murino-capitata***

5.1.1.1.1 Section ***Lepiota***

Spores large (more than 11 µm long), subfusiform, with a suprahilar depression; pileus covering a trichodermial palisade; clamp-connections present.

The only species known belonging to the section from Kerala is *Lepiota metulaespora*.

Type species: *Lepiota clypeolaria* (Bulliard) Kummer

Lepiota metulaespora (Berkeley & Broome) Saccardo. in Sylloge Fungorum 5:38 (1887)

Agaricus metulaesporus Berkeley. & Broome. in Journal of the Linnean Society, Botany 11: 512 (1871)

Lepiota clypeolaria variety *metulaespora* (Berkeley & Broome) Babos in Annales Historico-naturales Musei Nationalis Hungarici 53: 198 (1961)

Fig. 1. A-F; Pl. 1.

Basidiomata medium-sized. **Pileus** 28-31 mm diam., subglobose to ovoid when young, becoming conical to conico-convex and broadly

campanulate to convex on maturity, with an indistinct umbo; surface light orange (6A4, 6A5), brownish orange (6C7) or light brown (6D7) at the disc, whitish to yellowish white (3A2) elsewhere, covered with furfuraceous-fibrillose squamules in broken, almost concentric rings, denser towards the centre, forming a somewhat smooth to pruinose disc; margin initially incurved, becoming straight, finely striate in some older specimens, appendiculate. **Lamellae** free, whitish, crowded, up to 6 mm wide, with lamellulae in 4-6 tiers; edge finely fimbriate under a lens, concolorous with the sides. **Stipe** 85-89 × 5-6 mm, central, terete, equal, fistulose, becoming hollow; surface whitish to yellowish white (3A2) turning light brown (6D6, 6D7) on bruising or when cut, with floccose squamules scattered over the entire surface, furfuraceous towards the base; base arising from white mycelial cords. **Annulus** superior, fibrillose, descending, persistant as disrupted fibrillose remnants. **Context** up to 3 mm thick, white. **Odour** not distinctive. **Spore-print** white.

Spores 11-19 × 4-5 (14.5 ± 2 × 4.7 ± 0.44) µm, Q = 2.6-3.8, Qm = 3.1, subfusoid with a suprahilar depression, ellipsoid in top view, hyaline, with oil guttules, smooth, slightly thick- to thick-walled, dextrinoid, non-metachromatic in cresyl blue, cyanophilic in cotton blue. **Basidia** 21-33 × 8-11 µm, clavate, with guttulate contents, bearing 4 sterigmata up to 4 µm long. **Lamella-edge** sterile. **Cheilocystidia** crowded, 19-43 × 8-18 µm, versiform: utriform, clavate, oblong, ellipsoid, obovoid, or strangulated, rarely lageniform, most with crystalline encrustations on the surface, hyaline, thick-

walled. **Pleurocystidia** absent. **Lamellar trama** subregular; hyphae 2-8 µm wide, inflated up to 28 µm, hyaline to pale yellowish, thin-walled, septate, inamyloid. **Subhymenium** cellular. **Pileal trama** interwoven; hyphae 5-26 µm wide, inflated, hyaline, thin- to slightly thick-walled, inamyloid. **Pileal covering** a trichodermial palisade; terminal elements 15-164 × 4-19 µm, clavate, cylindric, ellipsoid, utriform, oblong, strangulated, thick-walled (up to 1 µm), with pale yellow to brownish plasmatic and membrane pigments. **Stipe covering** a trichodermial palisade; terminal elements 13-132 × 5-16 µm, versiform: clavate, cylindric, ellipsoid, utriform, oblong, or strangulated, thick-walled, and with pale yellowish to brownish plasmatic and wall pigments. Clamp-connections present on all hyphae.

Habitat: On soil among decaying leaf litter, solitary.

Known Distribution: AFRICA, Brazil, China, EUROPE, India, Mexico, Sri Lanka, USA.

Collections examined — Malappuram District, Calicut University Campus: 28 June 2006, AK401; 7 July 2006, AK414; 7 August 2006, AK414a.

Except for the presence of crowded cheilocystia, the present collection has characters that readily agree with the description of the species from Sri Lanka (Pegler 1972, 1986). The species has already been reported from India (Natarajan & Manjula 1983; Manjula 1983).

Reid (1958) described *Lepiota ventriosospora* from Britian which he stated to be a very closely related species that mainly differs by having a yellowish or pinkish veil, a non-striate pileal margin, and a thick flesh and by being more robust. In addition, the dark brown fibrillose scales on the pileus as well as dark brown more or less spiral bands towards the stipe base are differentiating features.

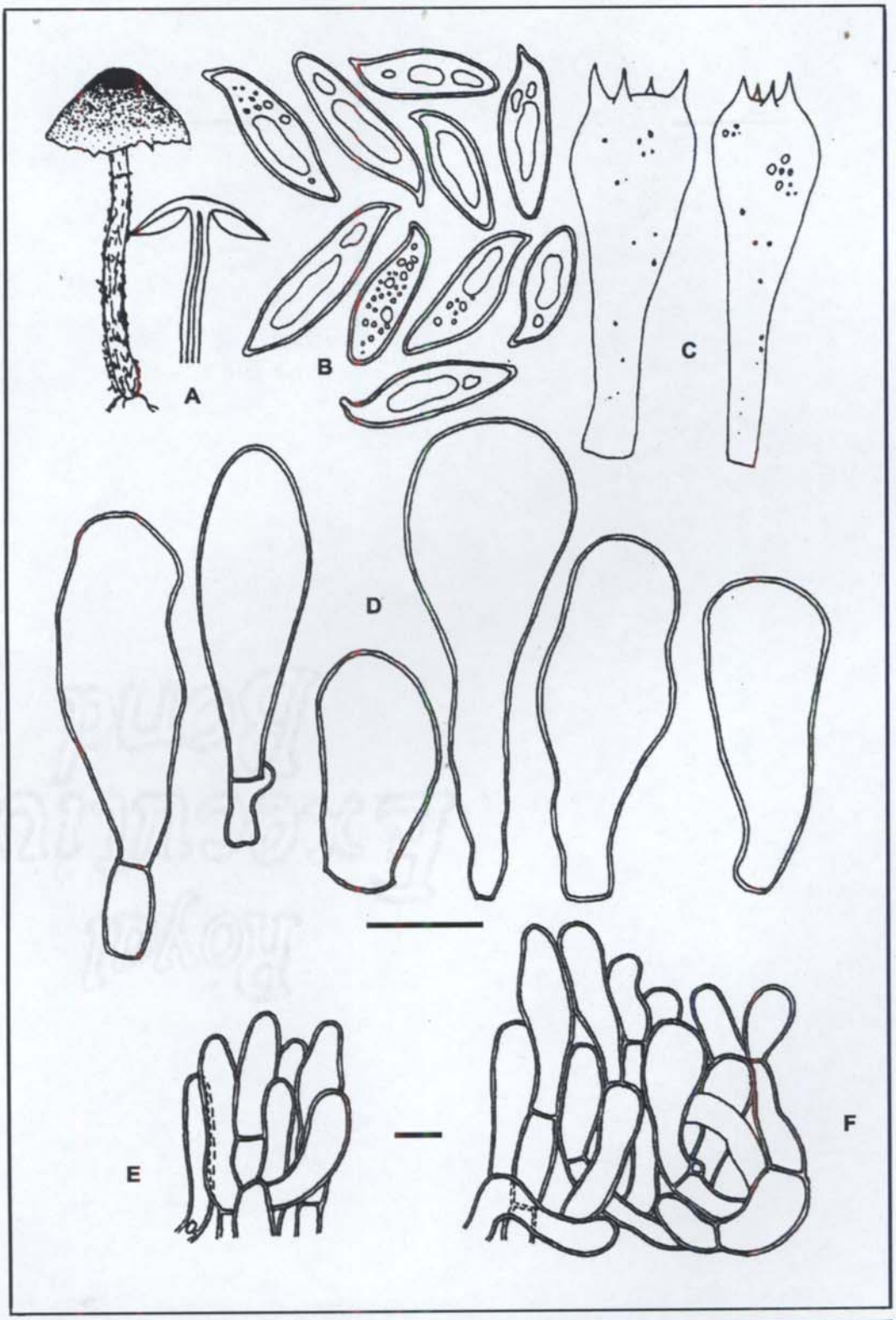


Figure 1. *Lepiota metulaespora* **A.** Habit x 1 **B.** Spores **C.** Basidia **D.** Cheilocystidia **E.** Stipe covering **F.** Pileus covering. Bars = 10 µm.

5.1.1.1.2 Section ***Stenosporae*** (Lange) Kuhner in Bulletin de la Société mycologique de France 52:190 (1936)

Spores with a strongly protracted base or spurred; pileal covering with more or less erect trichodermial terminal elements; clamp-connections present.

Type species: *Lepiota pseudofelina* Lange

Lepiota griseovirens Maire in Bulletin trimestriel de la Société mycologique de France 44: 37 (1928)

> *Lepiota griseovirens* subspecies *obscura* Locquin in Bulletin mensuel de la Société Linnéenne de Lyon 14: 61-62 (1945) (not valid)
>
> *Lepiota griseovirens* variety *obscura* Bon in Documents Mycologiques 6: 44 (1976)
>
> *Lepiota obscura* (Locquin) Babos in Annales historico-naturales Musei nationalis hungarici 50: 89 (1958) (not valid)
>
> *Lepiota obscura* (Bon) Bon in Documents Mycologiques 23: 33 (1993)
>
> *Lepiota grangei* form *brunneoolivacea* Pilát in Acta musei nationalis Pragae 11B: 9 (1955)

Fig. 2. A-F; Pl. 2. A & B.

Basidiomata small to somewhat medium-sized. **Pileus** 20-37 mm diam., conico-campanulate when young, becoming broadly convex to applanate, broadly umbonate; surface yellowish white (3A2), with fine, olive brown (4F4) squamules that are more concentrated towards the disc and sparse towards the margin, non-striate; margin initially incurved, soon becoming straight, initially entire, fissile with age. **Lamellae** free, white,

turning yellowish white (4A2) to pale yellow (4A3), crowded, up to 4 mm wide, with lamellulae in 3-4 tiers; edge finely fimbriate under a lens, concolorous with the sides. **Stipe** 25-75 × 2-4 mm, central, terete, almost equal with a slightly expanded to bulbous base, solid, becoming fistulose; surface orange white (5A2, 6A2) with scattered olive brown (4F4, 5F4) squamules, turning reddish brown (8E8) on bruising, fibrillose, rather villose towards base; base arising from white mycelial cords. **Annulus** superior, fibrillose, fugacious. **Context** up to 3 mm thick, white to yellowish white (3A2), turning reddish yellow (4B7) on exposure. **Odour** rather unpleasant. **Spore-print** white when freshly deposited turning cream-coloured on drying.

Spores 6.5-9 × 3-4 (8.4 ± 0.43 × 3.4 ± 0.3) µm, Q = 2.1-2.8, Qm = 2.52, subcylindric to bullet-shaped, often with a conspicuous spur, hyaline, with refractive guttules, thick-walled, smooth, dextrinoid, non-metachromatic in cresyl blue, cyanophilic in cotton blue. **Basidia** 17-22 × 7-8 µm, clavate, with guttulate contents, hyaline, bearing 4 sterigmata up to 5 µm long. **Lamella-edge** sterile. **Cheilocystidia** crowded, 12-25 × 6-9 µm, cylindrico-clavate to clavate, thin-walled, hyaline. **Pleurocystidia** absent. **Lamellar trama** subregular; hyphae 3-13 µm wide, inflated up to 25 µm wide, hyaline, thin-walled, inamyloid. **Subhymenium** cellular. **Pileal trama** parallel-interwoven; hyphae 2-6 µm wide, inflated up to 20 µm, hyaline, thin- to slightly thick-walled, inamyloid. **Pileal covering** a disrupted cutis forming trichodermial patches with erect and thick-walled terminal elements, 40-250 × 5-16 µm, cylindric to fusiform with acuminate, acute or obtuse tips, with

pale to dark grey plasmatic and wall pigments. **Stipe covering** a disrupted cutis forming trichodermial patches with erect or ascending cylindrical or clavate elements, 36-89 × 5-15 µm, thick-walled, with hyaline to yellow plasmatic and wall pigments. All hyphae with clamp-connections.

Habitat: On soil and decaying leaf litter, solitary or scattered in groups.

Known Distribution: ASIA, AFRICA, EUROPE

Collections examined — Malappuram District, Calicut University Campus: 9 August 2004, AK86; 10 August 2004, AK86a; 12 August 2004, AK86b; 13 August 2004, AK86c; 16 August 2004, AK86d; 17 August 2004, AK90; 15 October 2004, AK135; 9 November 2004, AK178; 30 June 2005, AK325; 15 October 2006, AK458.

Lepiota griseovirens is characterized by dark grey to olive brown squamules especially at the centre with some shades of green olive or blue on a yellowish white background. All collections of this species from Kerala are in close agreement with its description given by Candusso and Lanzoni (1990), Vellinga and Huijser (1993), Britenbach and Kranzlin (1995), Bon (1996) and Vellinga (2001a), except for minor variations in basidial and cystidial dimensions. This is the first report of the species from India.

A related species, *Lepiota grangei* (Eyre) Kuhner resembles *L. griseovirens* in gross morphology as evident from a colour photograph of that

species from Switzerland (Britenbach and Kranzlin, 1995), but could be separated based on its distinctly larger spores and mostly septate elements (normally with up to three clampless septa) of pileal covering with fine encrusted pigmentation. *Lepiota poliochloodes* Vellinga and Huijser, another greenish member, differs in having lighter pileal squamules, slightly smaller spores and clavate pileal end-cells. *Lepiota pilodes* Vellinga and Huijser differs mainly by its broad cheilocystidia and thin-layered pileal elements at the disc.

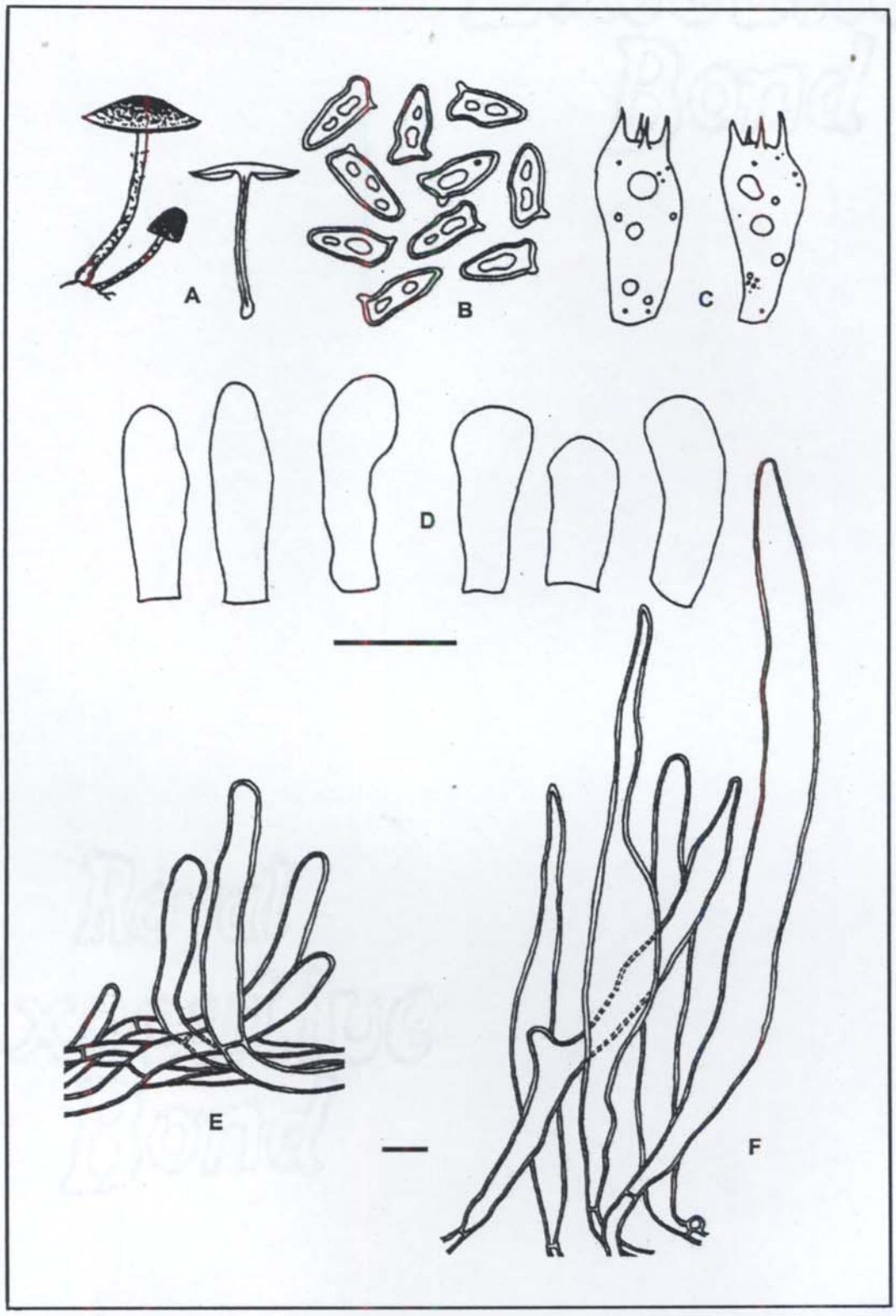


Figure 2. *Lepiota griseovirens* **A.** Habit x 1 **B.** Spores **C.** Basidia **D.** Cheilocystidia **E.** Stipe covering **F.** Pileus covering. Bars = 10 µm.

Plate 1. *Lepiota metulaespora* x 1.5

Plate 2. *Lepiota griseovirens,* **A.** x 2, **B.** x 1

Lepiota erythrosticta (Berkeley & Broome) Saccardo in Sylloge Fungorum 5: 62 (1887)

Agaricus erythrostictus Berkeley & Broome in Journal of the Linnean Society, Botany 11: 508 (1871)

Fig. 3. A-F; Pl. 3.

Basidiomata small. **Pileus** 11-30 mm diam., parabolic when young, becoming convex, broadly convex or applanate with a broad umbo at the disc; surface with brownish orange (7C8) to light brown (7D8) squamules on a pale yellow (4A3) background, non-striate; squamules concentrated and erect or recurved at the disc, appressed and sparse elsewhere; margin initially incurved, later straight, entire to appendiculate. **Lamellae** free, yellowish white (3A2), crowded, up to 3 mm wide, with lamellulae in 3-6 tiers; edge finely fimbriate under a lens, concolorous with the sides. **Stipe** 33-50 × 1.5-2 mm, central, terete, equal, fistulose, becoming hollow with age; surface concolorous with the pileus, somewhat fibrillose; base arising from thick white mycelial cords. **Annulus** superior, fibrillose, fugacious. **Context** less than 1 mm thick, white to pale yellow (4A3). **Odour** not distinctive. **Spore-print** white.

Spores 6-9.5 (12) × 3-4 (7.5 ± 1.2 × 3.5 ± 0.31) µm, Q = 1.8-3.2, Qm = 2.2, bullet-shaped or subcylindric with a spurred base in side view, oblong to subcylindric in frontal view, hyaline, with refractive guttules, thick-walled, smooth, dextrinoid, non-metachromatic in cresyl blue, cyanophilic in cotton blue. **Basidia** 17-24 × 7.5-9 µm, clavate, with guttulate contents, bearing 4

sterigmata up to 5 µm long. **Lamella-edge** sterile with crowded cheilocystidia. **Cheilocystidia** 14-40 × 5.5-10 µm, cylindric, clavate or narrowly utriform, thin-walled, hyaline. **Pleurocystidia** absent. **Lamellar trama** subregular; hyphae 3-17 µm wide, inflated, hyaline, thin-walled, inamyloid. **Subhymenium** cellular. **Pileal trama** interwoven; hyphae 2-15 µm wide, inflated, thin-walled, septate, inamyloid. **Pileal covering** a disrupted cutis forming almost a trichodermium towards the disc; terminal elements 25-125 × 6-12 µm, cylindrico-clavate to subfusoid, thin- to slightly thick-walled, with brown plasmatic pigment. **Stipe covering** a disrupted cutis or almost trichodermial at places with ascending or erect, clavate terminal elements, 25-91 × 6-14 µm, thin-walled, with brown plasmatic pigment. All hyphae with clamp-connections.

Habitat: On soil among decaying leaf litter, solitary or scattered,

Known Distribution: The Lesser Antilles, New Guinea, Trinidad, Sri Lanka

Collections examined — Malappuram District, Calicut University Campus: 10 November 2003, AK11; 5 October 2004, AK119; 7 October 2004, AK119a; 5 October 2004, AK122; 9 November 2004, AK175; 10 Novenber 2004, AK175a; 24 July 2006, AK119b; 18 July 2006, AK418; 27 September 2006, AK449.

The species has a basidiomata covered with bright reddish brown squamules that gives it a striking appearance. It is characterized by yellowish white lamellae, spores with an abaxial protraction, crowded cylindric, clavate or utriform cheilocystidia and erect cylindrico-clavate to subfusoid terminal elements with brown plasmatic pigment in the pileal covering.

The Kerala collections agree with the description of the species by Pegler (1972, 1986), but differ by the lack of a distinct lilaceous or vinaceous tint on the pileal surface. Dennis (1952) recorded smaller spores (5-6 × 3 µm) from the material from Trinidad. This is the first record of the species from India.

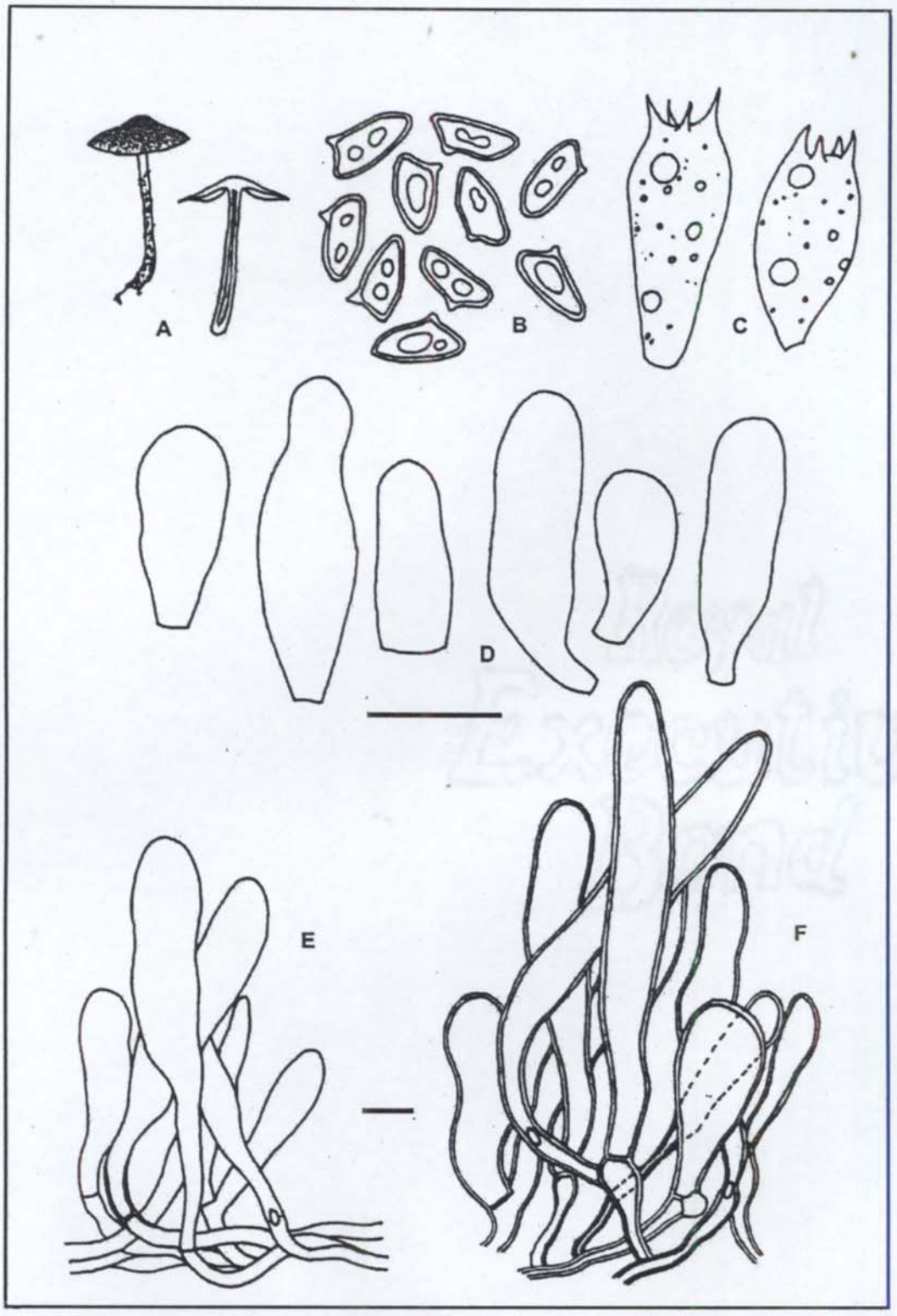


Figure 3. *Lepiota erythrosticta* **A.** Habit x 1 **B.** Spores **C.** Basidia **D.** Cheilocystidia **E.** Stipe covering **F.** Pileus covering. Bars = 10 µm.

Lepiota castanea Quélet in Compte rendu de l' Association française pour l' advancement des sciences (Reims, 1880) 9: 661 (1881) (Champignons Jura Vosges Supplement 10)

> *Lepiota ignicolor* Bresadola in Fungi Tridentini novi vel nondum delineati descripti et iconibus illustrate. Trento 2:3 (1892)
>
> *Lepiota ignipes* Locquin in Bulletin Mensuel de la Société Linnéenne de Lyon 14: 59 (1945)
>
> *Lepiota ignipes* Locquin ex Bon in Documents Mycologiques 8 (30-31): 70 (1978)

Fig. 4. A-F; Pl. 4.

Basidiomata small. **Pileus** 10-12 mm diam., subglobose when very young, becoming campanulate to convex, with an indistinct umbo; surface brown (7E8), uniformly covered with dense fibrillose-tomentose squamules, barely revealing the underlying paler surface; squamules recurved to almost erect at the disc; margin initially incurved, becoming straight, entire. **Lamellae** free, whitish to yellowish white (3A2) or pale yellow (3A3), moderately crowded, up to 1 mm wide, with lamellulae in 2-3 tiers; edge finely fimbriate under a lens, concolorous with the sides. **Stipe** 28-34 × 1 mm, central, terete, equal, slightly bulbous at the base, solid, becoming slightly fistulose; surface light brown (6D8) with broken, zonate, brown (7E8) squamules, fibrillose; base arising from white mycelial cords. **Annulus** superior, fibrillose, evanescent or remaining as disrupted fibrillose fragments. **Context** up to 2 mm thick at the disc, yellowish white (3A2). **Odour** not distinctive. **Spore-print** not obtained.

Spores 9-12 × 3.5-4.5 (10.3 ± 1 × 4 ± 0.22) µm, Q = 2.2-3, Qm = 2.5, ellipsoid or almost fusoid, with a strongly protracted base, some with a suprahilar depression, cylindrical in top view, hyaline, with oil guttules, smooth, slightly thick-walled (up to 0.5 µm), dextrinoid, non-metachromatic in cresyl blue, cyanophilic in cotton blue. **Basidia** 20-31 × 8-11 µm, clavate, with guttulate contents, bearing 4 sterigmata up to 5 µm long. **Lamella-edge** sterile. **Cheilocystidia** crowded, 12-51 × 5-8 µm, flexuose, cylindrical, clavate, or utriform, some septate, rarely with apical branching, hyaline to pale yellowish, thin-walled. **Pleurocystidia** absent. **Lamellar trama** subregular; hyphae 4-21 µm wide, inflated, hyaline to pale yellowish, thin- to slightly thick-walled, septate, inamyloid. **Subhymenium** cellular. **Pileal trama** interwoven; hyphae 4-18 µm wide, inflated, hyaline to yellowish, slightly thick-walled (up to 0.5 µm), inamyloid. **Pileal covering** a trichodermium; terminal elements 31-256 × 6-17 µm, clavate and fusoid or rarely cylindrical, with obtuse tips, thick-walled (up to 1.5 µm), with brown plasmatic, membrane and encrusting pigments. **Stipe covering** made of 3-10 µm wide, hyaline to pale yellowish, thick-walled (1.5 µm) hyphae, highly disrupted by trichodermial patches of erect terminal elements; terminal elements up to 212 µm long and 3-9 µm wide, fusoid with obtuse or acuminate apex, thick-walled and with brownish plasmatic and membrane pigments. Clamp-connections present on all hyphae.

Habitat: On soil among decaying leaf litter, solitary.

Known Distribution: AFRICA, ASIA, EUROPE, USA

Collections examined — Idukki District, Munnar: 9 June 2006, AK392; 10 June 2006, AK392 a.

The present collection fits in well with the description of the species given by Vellinga (2001a) except that the septations of the pileal elements are not well-developed. *Lepiota castanea* is a highly variable species displaying a wide range in macroscopic and microscopic characters. The species is common in Europe, North America and in temperate Asia. It is no surprise that the fungus was encountered from the Munnar area of Kerala where temperate climatic conditions prevail. This is the first report of the species from India.

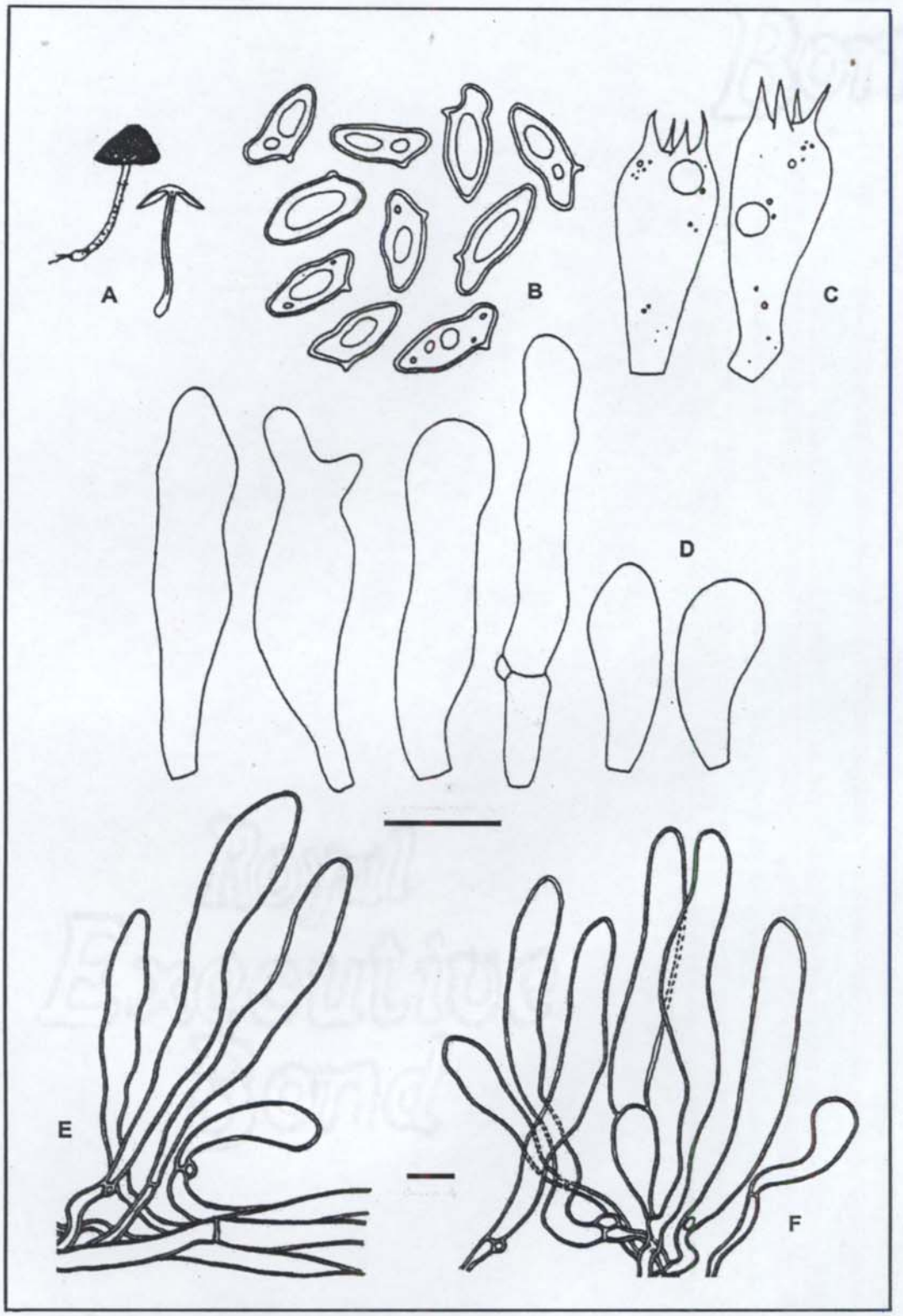


Figure 4. *Lepiota castanea* **A.** Habit x 1 **B.** spores **C.** Basidia **D.** Cheilocystidia **E.** Stipe covering **F.** Pileus covering. Bars = 10 µm.

Plate 3. *Lepiota erythrosticta* x 2

Plate 4. *Lepiota castanea* x 3

5.1.1.1.3 Section ***Echinatae*** Fayod in Annales des sciences naturalles, sér. VII, Botanique 9: 350 (1889)

Pileus covering wooly-floccose and spiny, made up of ellipsoid to globose elements in agglutinated chains; spores ellipsoid to subcylindric, dextrinoid; clamp-connections present, rarely absent.

Type species: *Lepiota acutesquamosa* (Weinmann) Kummer

Lepiota pseudoasperula (Knudsen) Knudsen in Botanical Tidsskrift 75: 128 (1980)

Cystolepiota pseudoasperula Knudsen in Botanical Tidsskrift 73: 125 (1978)

Echinoderma pseudoasperulum (Knudsen) Bon in Documents mycologiques 21: 63 (1991)

Fig. 5. A-E; Pl. 5.

Basidiomata small. **Pileus** 4-22 mm diam., globose when young, becoming broadly convex to applanate on maturity, with an indistinct umbo; surface light orange (5A4, 5A5), furfuraceous and covered with erect, brown (7E5, 7E6) squamules which are darker and more concentrated towards the disc; margin incurved, becoming straight, appendiculate, fissile with age. **Lamellae** free, light orange (5A4, 5A5), close to moderately crowded, up to 2 mm wide, with lamellulae in 3 tiers; edge finely fimbriate under a lens, concolorous with the sides. **Stipe** 10-25 × 1-2 mm, central, terete, equal or slightly expanding towards sometimes bulbous at the base, solid; surface brownish orange (5C5) turning brown (7E5) with age or on bruising,

speckled with brown (7E5) scales in a zonate manner; base arising from white mycelium. **Annulus** superior, fibrillose. **Context** up to 2 mm thick, light orange (5A4). **Odour** pleasant. **Spore-print** white.

Spores 4-6 × 2-3 (4.7 ± 0.55 × 2.9 ± 0.2) µm, Q = 1.3-2, Qm = 1.6, oblong-ellipsoid to subcylindric, hyaline, with oil guttules, smooth, thin- to slightly thick-walled, dextrinoid, non-metachromatic in cresyl blue, cyanophilic in cotton blue. **Basidia** 12-20 × 4-6 µm, cylindrico-clavate, with guttulate contents, bearing 4 sterigmata up to 5 µm long. **Lamella-edge** fertile. **Cheilocystidia** absent. **Pleurocystidia** absent. **Lamellar trama** subregular; hyphae thin-walled, septate, hyaline to yellow or pale brown, 2-20 µm wide, inflated, inamyloid. **Subhymenium** cellular. **Pileal trama** interwoven, of 4-5 µm wide, inflated, hyaline to pale yellow, thin-walled, inamyloid hyphae. **Pileal covering** made up of parallel, loosely interwoven, 3-10 µm wide, thin-walled, pale brown to dark brown hyphae giving rise to short, erect chains of globose (14-26 µm diam.) to ellipsoid (15-36 × 7-25 µm) inflated elements, which often aggregate to form conical bundles, with brown to dark brown plasmatic pigments and thin- to slightly thick-walls. **Stipe covering** a loosely arranged cutis of 2-15 µm wide, thin-walled, pale yellow, golden yellow or brown, filamentous hyphae giving rise to fascicles of globose (15-32 µm diam.), to ellipsoid (15-42 × 15-24 µm) inflated elements. All hyphae with abundant clamp-connections.

Habitat: On soil, among decaying leaf litter, scattered in troops under *Acacia* trees.

Known Distribution: Argentina, EUROPE, USA.

Collections examined — Malappuram District, Calicut University Campus: 26 October 2004, AK145; 1 November 2004, AK145a; 2 November 2004, AK162; 4 November 2004, AK162a; 5 November 2004, AK173; 10 November 2004, AK145b.

This agaric which lack cystidia has all the characters of the species described by Knudsen (1978). Knudsen originally designated this species under the genus *Cystolepiota* but subsequently Knudsen (1980) transferred it to *Lepiota*. The slight variations noticed in the Kerala collections from the earlier descriptions (Knudsen 1978, 1980; Candusso & Lanzoni 1990; Vellinga 2001f) are an appendiculate margin (margin recorded as 'even' in Knudsen 1978) and the slightly smaller dimensions of the pileal elements in the present specimens. Knudsen (1978, 1980) mentioned that the spore-print was never seen and Vellinga opines it to be probably white. From the data collected during this study, spore-print colour was noted as white. The Kerala collections seem to be the first record of the species from Asia.

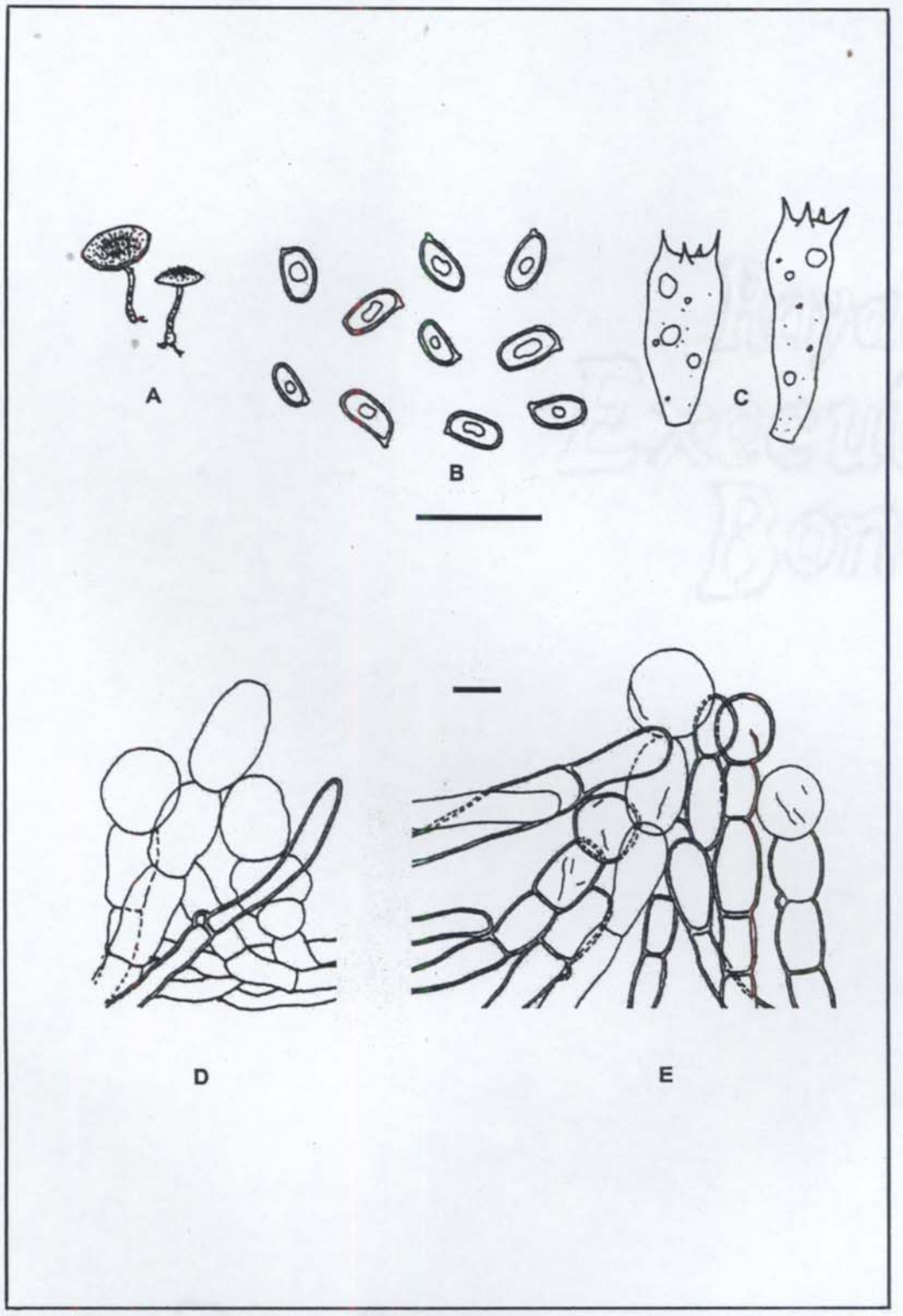


Figure 5. *Lepiota pseudoasperula* **A.** Habit x 1 **B.** Spores **C.** Basidia **D.** Stipe covering **E.** Pileus covering. Bars = 10 µm.

***Lepiota* species 3**

Fig. 6. A-F.

Basidioma somewhat medium-sized. **Pileus** 30 mm diam., broadly convex, becoming applanate, with a broad indistinct umbo; surface brown (6E6), with dark brown (6F8) squamules; squamules pyramidal at the disc, appressed and radiating towards margin; margin incurved, becoming straight, eroded and fissile with age. **Lamellae** free, initially white, turning yellowish white (4A2) to pale yellow (4A3), crowded, up to 5 mm wide, with lamellulae in 3-4 tiers; edge finely fimbriate under a lens, concolorous with the sides. **Stipe** 35 × 2 mm, central, terete, equal, fistulose; surface brown (6E6) becoming dark brown (6F8) with age, fibrillose; base arising from white mycelium. **Annulus** superior, fibrillose, evanescent. **Context** less than 2 mm thick, yellowish white (4A2). **Odour** not distinctive. **Spore-print** not obtained.

Spores 4.5-7 × 3-4 (6.2 ± 0.8 × 3.6 ± 0.4) µm, Q = 1.25-1.8, Qm = 1.6, ovo-ellipsoid to oblong-ellipsoid, hyaline, with refractive guttules, thick-walled, smooth, weakly dextrinoid, non-metachromatic in cresyl blue, cyanophilic in cotton blue. **Basidia** 10-17 × 6-8 µm, cylindrico-clavate to clavate, hyaline, bearing 4 sterigmata up to 3 µm long. **Lamella-edge** sterile. **Cheilocystidia** crowded, 13-34 × 10-20 µm, inflated-clavate, sphaeropedunculate or pedicellate-ovoid, hyaline, thin-walled. **Pleurocystidia** absent. **Lamellar trama** subregular; hyphae 2-21 µm wide, inflated, hyaline, thin-walled, inamyloid. **Subhymenium** cellular. **Pileal**

trama interwoven; hyphae 2-10 µm wide, often inflated up to 20 µm wide, hyaline, thin-walled, septate, inamyloid. **Pileal covering** a disrupted cutis of filamentous hyphae, 3-15 µm wide, with transitions to trichodermial patches of erect hyphal bundles terminated by chains of short end cells; almost entirely trichodermial at the centre with agglutinated conical bundles reaching up to 500 µm in length; terminal cells 12-47 × 6-18 µm, cylindrical, ellipsoid, subglobose or clavate, thin- to slightly thick-walled with brown to dark brown plasmatic and membrane pigments. **Stipe covering** a cutis of repent, 2-10 µm wide, hyaline to pale yellowish brown hyphae with a few ascending terminal elements; terminal elements 20-32 × 5-9 µm, cylindrical, thin-walled, hyaline to pale yellow. All hyphae devoid of clamp-connections.

Habitat: On decaying leaf litter, solitary.

Known Distribution: Only from the type locality.

Collection examined — Kannur District, near Neeliyarkottam: 16 October 2004, AK139.

This species is characterized by a pileus with pyramidal squamules, ovo-ellipsoid to oblong-ellipsoid spores, vesicular cheilocystidia, pileal covering composed of agglutinated chains of cylindrical, ellipsoid, subglobose or clavate end-cells, and by the absence of clamp-connections.

The present collection resembles species of *Lepiota* section *Echinatae* although affinities with the genus *Cystolepiota* in the nature of pileal covering and in the weakly dextrinoid spores are evident. According to Vellinga (2001f) a velar structure with 'thin hyphae gradually transient into globose to ellipsoid elements, agglutinated to form pyramidal squamules' is characteristic of *Lepiota* section *Echinatae*. Following this observation, the present species is better placed in the genus *Lepiota*. However, this species remains distinct by virtue of the fibrillose fugacious annulus, weakly dextrinoid spores and by its clampless hyphae and moreover do not match with any of the previously described taxa under *Lepiota* or *Cystolepiota*. *Lepiota efibulis* Knudsen is a related species in *Lepiota* section *Echinatae* that lack clamp-connections (Knudsen 1980; Vellinga 2001a) but chiefly differs from the present collection in their distinct membranous annulus and much smaller spores that are metachromatic in cresyl blue.

***Lepiota* species 5**

Fig. 7. A-F; Pl. 6.

Basidiomata small. **Pileus** 20-30 mm diam., initially subglobose, gradually parabolic or conico-convex and finally convex; surface light brown (7D5) to reddish brown (8E6) or dark brown (7F8), with abundant warty to conical or echinate, concolorous, detersile squamules, which upon detachment leaves a darker reticulate pattern on a lighter pileal background, more concentrated towards the disc and sparser towards the margin, finely fibrillose, non-striate; pellis peeling off as a layer from the margin on maturity exposing the context; margin initially incurved, later straight, eroded. **Lamellae** free, white, moderately crowded to crowded, up to 7 mm wide, with lamellulae in 4-5 tiers; edge finely fimbriate under a lens, concolorous with the sides. **Stipe** 32-40 × 2-5 mm, central, terete, almost equal, fistulose, becoming hollow with age; surface light brown (7F8) to reddish brown (8E6), with scattered pyramidal superficial squamules, whitish above the annulus and when young, minutely fibrillose; base arising from white mycelium. **Annulus** superior, membranous-fibrillose, ascending, movable, densely covered with whitish to light brown (7D5) floccose squamules on the lower side. **Context** up to 6 mm thick, white. **Odour** not distinctive. **Spore-print** not obtained.

Spores 4-6 × 3 (5 ± 0.44 × 3 ± 0) µm, Q = 1.3-2, Qm = 1.6, ellipsoid, some with a slight hunch, hyaline, with refractive guttules, thin- to slightly

thick-walled, smooth, dextrinoid, non-metachromatic in cresyl blue, cyanophilic in cotton blue. **Basidia** 15-20 × 6-8 µm, cylindrico-clavate to clavate, with guttulate contents, hyaline, bearing 4 sterigmata up to 2 µm long. **Lamella-edge** sterile. **Cheilocystidia** crowded, 12-25 × 5-7 µm, clavate or utriform with a pedicel, thin-walled, interspersed by relatively few, inflated, loosely attached, slightly thick-walled (up to 0.5 µm), hyaline cylindrical, clavate, pyriform, utriform, ellipsoid or ovoid cells, 10-34 × 7-20 µm. **Pleurocystidia** absent. **Lamellar trama** subregular; hyphae 2-12 µm wide, hyaline, thin-walled, inamyloid. **Subhymenium** cellular. **Pileal trama** interwoven; hyphae 2-15 µm wide, cylindrical, hyaline to pale yellow, thin-walled, inamyloid. **Pileal covering** a highly disrupted cutis of 2-17 µm wide hyphae with trichodermial patches of ascending or erect, loosely attached, branched and thick-walled (up to 1 µm) hyphal elements with brown to dark brownish plasmatic and membrane pigments; terminal elements 17-70 × 4-17 µm, cylindrical, ellipsoid, oblong or ovoid. **Stipe covering** a cutis of repent, filamentous, 2-13 µm wide, thin- to slightly thick-walled (up to 1 µm) hyphae with hyaline to pale grey plasmatic pigments, disrupted to form occassional trichodermial transitions at the scales with loosely attached, erect or ascending cylindrical, clavate or ovoid elements that are slightly thick-walled and with pale yellow to brownish plasmatic and wall pigments. Clamp-connections rarely observed.

Habitat: On soil and decaying leaf litter, solitary or scattered in groups.

Known Distribution: Only from the type locality.

Collections examined — Thiruvananthapuram District, Palode: 15 July 2005, AK352; 18 July 2005, AK353; 20 July 2005, AK366.

This is a distinct species of *Lepiota* section *Echinatae* characterized by ellipsoid spores that are dextrinoid, crowded cheilocystidia interspersed with inflated slightly thick-walled versiform cells and a pileal covering with loosely attached cylindrical, ellipsoid, oblong or ovoid terminal elements. The collections have distinctive reddish brown to dark brown pyramidal superficial squamules and a prominent ascending annulus densely covered with whitish to light brown floccose squamules. These characters together make it unique. Combination of characters of the present material does not match any published descriptions.

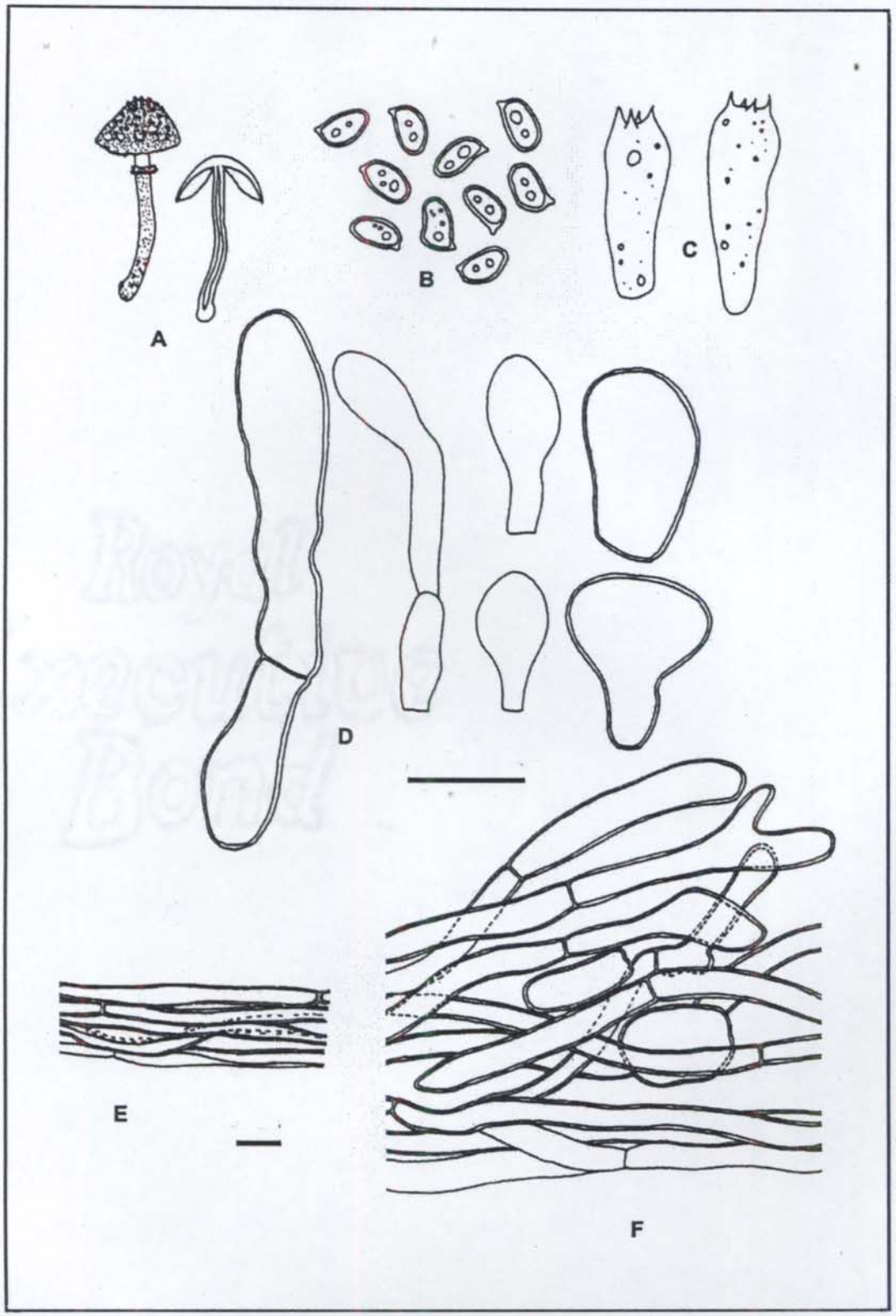


Figure 7. *Lepiota* species 5 **A.** Habit x 1 **B.** Spores **C.** Basidia **D.** Cheilocystidia **E.** Stipe covering **F.** Pileus covering. Bars = 10 µm.

Plate 5. *Lepiota pseudoasperula* x 2.5

Plate 6. *Lepiota* species 5 x 2.5

5.1.1.1.4 Section ***Ovisporae*** (Lange) Kuhner in Bulletin de la Société mycologique de France 52: 190 (1936)

Spores ellipsoid to oblong or amygdaliform, never fusoid and larger than 10 µm; pileal covering made of ellipsoid, cylindrical, fusoid or clavate elements; clamp-connections present.

Type species: *Lepiota subincarnata* Lange

Lepiota subincarnata Lange in Flora Agaricina Danica 5: V (1940)

> *Lepiota josserandii* Bon & Boiffard in Bulletin trimestriel de la Société mycologique de France 90: 289 ('1974') (1975)
>
> *Leucoagaricus josserandii* (Bon & Boiffard) Raithelhuber in Metrodiana 17: 75 (1989)
>
> *Lepiota subincarnata* variety *josserandii* (Bon & Boiffard) Gminder in Beiträge zur Kenntnis der Pilze Mitteleuropas 12: 69 (1999)
>
> *Lepiota josserandii* variety *rosabrunnea* Raithelhuber in Metrodiana 16: 42 (1988)

Fig. 8. A-F; Pl. 7.

Basidiomata small to medium-sized. **Pileus** 16-40 mm diam., subglobose when young, becoming broadly convex to applanate at maturity, with an indistinct umbo; surface orange white (5A2), with cinnamon brown (6D6) squamules; squamules concentrated more towards the disc, recurved at the disc, appressed towards margin; margin initially incurved, becoming straight, entire or slightly appendiculate, fissile with age. **Lamellae** free, initially white, turning yellowish white (1A2, 2A2) to cream-coloured (4A3) and finally orange white (5A2) with age, crowded, thin, up to 7 mm wide, with

lamellulae in 3-5 tiers; edge finely fimbriate under a lens, concolorous with the sides. **Stipe** 20-70 × 2-6 mm, central, terete, almost equal with a slightly bulbous base, initially solid, becoming fistulose and finally hollow; surface orange white (5A2) with cinnamon brown (6D6) fibrillose scales forming zonations; base arising from white mycelial cords. **Annulus** central to superior, fibrillose, evanescent. **Context** up to 3 mm thick, white. **Odour** mild, rather unpleasant. **Spore-print** white.

Spores 4.5-7.5 × 3-5 (6.2 ± 0.85 × 3.9 ± 0.38) µm, Q = 1.38-1.75, Qm = 1.58, oblong-ellipsoid, slightly thick-walled, hyaline, smooth, with refractive guttules, dextrinoid, non-metachromatic in cresyl blue, cyanophilic in cotton blue. **Basidia** 14-22 × 6-9 µm, clavate, 2-4 spored, sterigmata up to 3 µm long. **Lamella-edge** heteromorphous to almost sterile. **Cheilocystidia** crowded, 12-35 × 6-9 µm, clavate, hyaline, thin-walled. **Pleurocystidia** absent. **Lamellar trama** subregular; hyphae 2-11 µm wide and often inflated up to 25 µm wide, septate, hyaline, thin-walled, inamyloid. **Subhymenium** cellular. **Pileal trama** interwoven; composed of 2-10 µm wide, thin-walled, hyaline hyphae, inamyloid. **Pileal covering** a trichodermium appearing almost hymeniform at disc, of erect or ascending terminal elements up to 300 µm long and 6-19 µm wide, pale brown to brown, thin- to thick-walled (up to 1 µm), mostly sub-fusiform with gradually tapering apices, often branched, mixed with shorter cylindrical to ventricose elements at the base. **Stipe covering** a trichodermium with elements similar to that of pileal covering. All hyphae with clamp-connections.

Habitat: On decaying leaf litter, at times solitary or in scattered groups.

Known Distribution: AFRICA, EUROPE, USA

Collections examined — Malappuram District, Calicut University Campus: 29 August 2003, AK2; 11 November 2003, AK2a; 23 July 2004, AK78; 25 July 2004, AK78a; 4 October 2004, AK118; 5 October 2004, AK118a; 5 October 2004, AK 120; 6 October 2004, AK118b; 7 October 2004, AK118c; 26 October 2004, AK151; 29 September 2006, AK452.

The material of this species from Kerala is in close agreement with the description of the species by Pegler (1977) and Vellinga (2001a). The present collections slightly differ from the earlier descriptions in having a basal layer of pileal elements made up of cylindrical to ventricose elements along with the fusiform elements. This species is distinguished by cinnamon brown squamules on a paler pileal background, oblong-ellipsoid spores, clavate cheilocystidia, and a pileal covering made up of mostly subfusiform elements up to 400 µm long. This character combination places this species under the section *Ovisporae* (Lange) Kühner. This forms the first report of the species from India.

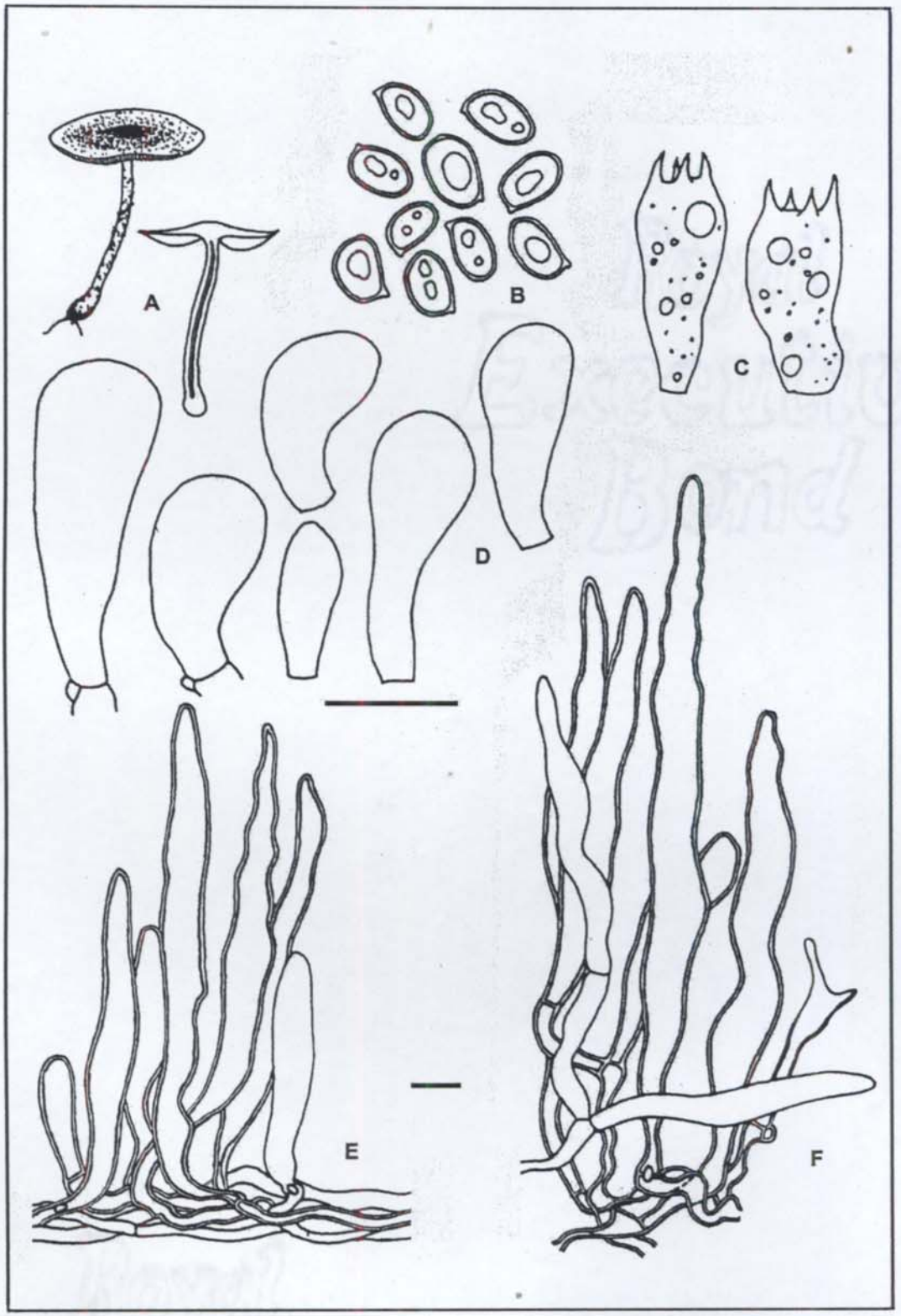


Figure 8. *Lepiota subincarnata* **A.** Habit x 1 **B.** Spores **C.** Basidia **D.** Cheilocystidia **E.** Stipe covering **F.** Pileus covering. Bars = 10 µm.

***Lepiota* species 8**

Fig. 9. A-F; Pl. 8.

Basidiomata small but robust. **Pileus** 19-27 mm diam., subglobose when young, becoming convex to broadly convex, finally applanate, slightly umbonate at the disc when young but umbo usually becomes indistinct with maturity; surface entirely covered with light brown (6D4, 6D5) to brown (6E5), granular to appressed fibrillose squamules on a dull white background with areolate cracking towards the margin, pruinose to smooth at the disc; pileal covering peels off as a layer from the margin exposing the white context; margin initially incurved, later straight, appendiculate. **Lamellae** free, initially whitish, turning yellowish white (4A2) with age, moderately crowded, up to 4 mm wide, with lamellulae in 3-5 tiers; edge finely fimbriate under a lens, concolorous with the sides. **Stipe** 25-34 × 4-5 mm, central, terete, almost equal, with a subbulbous to bulbous base, fistulose becoming hollow with age; surface whitish to orange white (5A2) or light brown (6D4) turning brownish orange (7C3) on bruising, with discrete, fibrillose, dark brown (6E8) squamules forming broken girdles towards the lower portion of the base; base arising from white mycelial cords. **Annulus** as a distinct zone of dark brown (6E8) persistent fibrillose squamules, occupying an inferior to central position on the stipe. **Context** up to 2 mm thick, whitish. **Odour** not distinctive. **Spore-print** white.

Spores 4.5-6 × 3-4.5 (5.28 ± 0.82 × 3.8 ± 0.36) µm, Q = 1.2-1.7, Qm = 1.39, ovo-ellipsoid to ellipsoid, hyaline, with oil guttules, smooth, thick-

walled (up to 1 µm), dextrinoid, non-metachromatic in cresyl blue, cyanophilic in cotton blue. **Basidia** 20-25 × 6-8 µm, clavate, with guttulate contents, bearing 4 sterigmata up to 4 µm long. **Lamella-edge** sterile. **Cheilocystidia** crowded, 12-32 × 5.5-10 µm, cylindrico-clavate, clavate, broadly clavate, utriform, obpyriform, some with a subcapitate or rarely prolongated apex (up to 30 µm long), at times septate, slightly inflated, hyaline, thin-walled. **Pleurocystidia** absent. **Lamellar trama** subregular; hyphae 2-10 µm wide, hyaline, thin-walled, septate, inamyloid. **Subhymenium** cellular. **Pileal trama** interwoven; hyphae 2-16 µm wide, inflated, hyaline to pale yellowish, thin- to slightly thick-walled, inamyloid. **Pileal covering** a trichodermium with erect or ascending terminal elements; terminal elements 36-120 × 7-23 µm, mostly fusoid or cylindric with obtuse tips, younger elements invariably clavate, thick-walled (up to 1 µm), with brownish to dark brownish plasmatic and membrane pigments. **Stipe covering** a cutis with occasional trichodermial patches of ascending or erect, cylindric, fusoid or clavate terminal elements 40-125 × 7-23 µm, with thick walls (up to 1 µm) and brownish to dark brown plasmatic and membrane pigments. All hyphae with clamp-connections.

Habitat: On soil, solitary.

Known Distribution: Only from the type locality.

Collections examined — Calicut District, Puthiyangadi: 24 September 2006, AK442; 9 October 2006, AK453; 11 November 2006, AK442a; 27 November 2006, AK442b.

This species clearly belongs to the section *Ovisporae*, but stands out from all the species described in that section owing to its unique combination of characters. The small spores, versiform cheilocystidia with occasional apical outgrowths and the rather short (36-120 µm long), clavate, fusoid or cylindric pileal elements with brown to dark brown plasmatic and membrane pigments are diagnostic of this species. *Lepiota helveola* Bresadola, a species with a world-wide distribution (Guzmán & Guzmán-Davalos 1992), seems to be a related species with almost similar cheilocystidial shapes and dimensions. Also, the elements of pileal covering in both species show a close morphological semblance. However, *L. helveola* has larger basidiomata (Bon 1996: 57) and possess conspicuously larger spores (see Huijsman (1962) and Migliozzi (1997). *Lepiota pseudohelveola* Kühner ex Hora also differs being a bigger species. However, a colour photograph of that species presented by Migliozzi (1997: 332) shows noticeable similarity to the Kerala collections. A distant similarity with the descriptions of *Lepiota azalearum* (Murrill) Dennis (Dennis 1952, 1970; Pegler 1983) could be attributed but this fungus clearly differs by its reddish brown pileus, evanescent annulus, spores that are less broad (2.5-3 µm), and fusiform pileal elements with pointed apex.

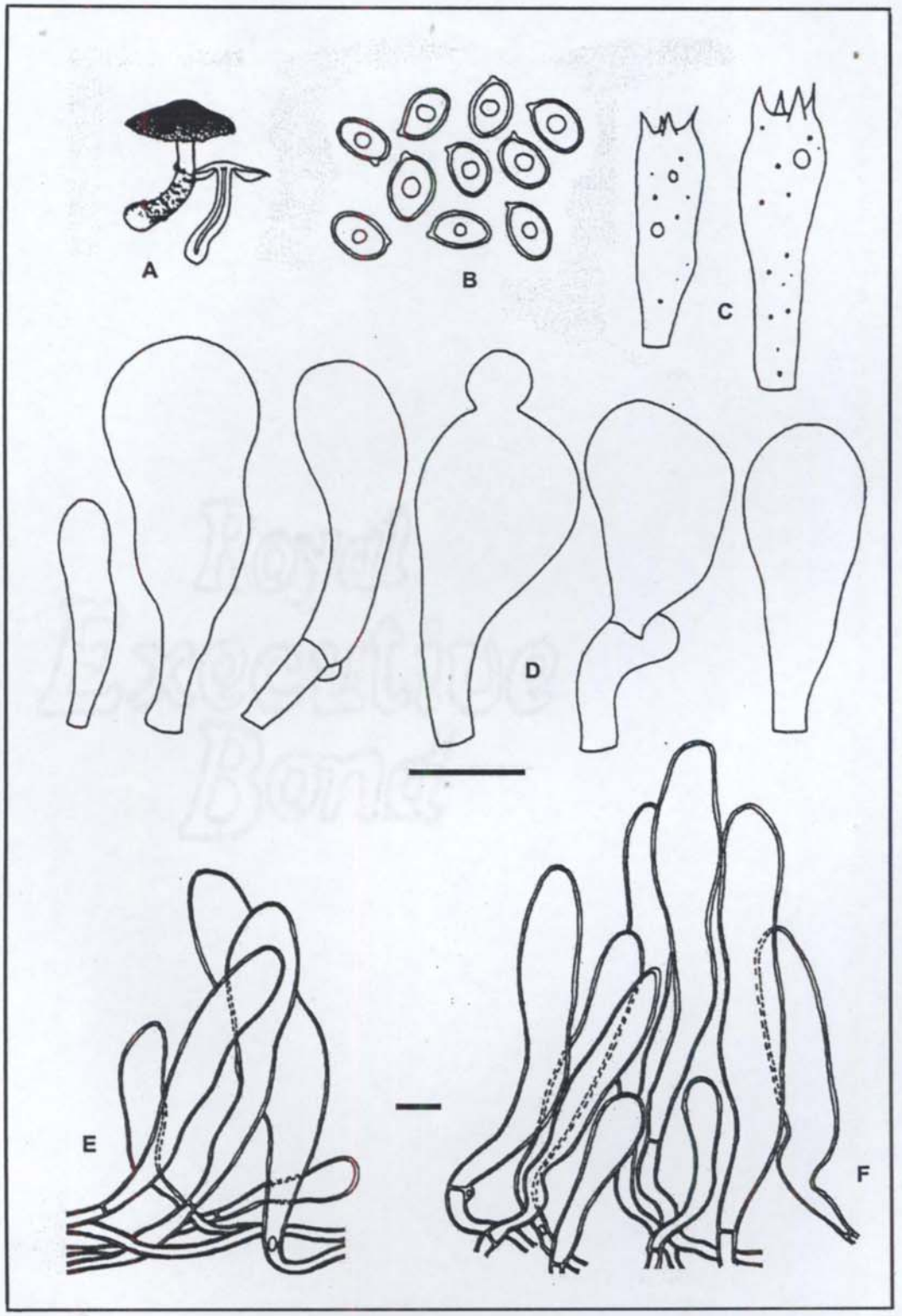


Figure 9. *Lepiota* species 8. **A.** Habit x 1 **B.** Spores **C.** Basidia **D.** Cheilocystidia **E.** Stipe covering **F.** Pileus covering. Bars = 10 µm.

Plate 7. *Lepiota subincarnata* x 1.5

Plate 8. *Lepiota* species 8 x 3

Lepiota brevipes Murrill in Journal of the Florida Academy of Science 8: 178 (1945)

Fig. 10. A-F; Pl. 9.

Basidiomata small. **Pileus** 4-17 mm diam., initially subglobose, becoming broadly convex to applanate, with or without an indistinct umbo; surface yellowish white (3A2), pale yellow (4A2) or cream-coloured (4A3) with brown (7D8, 7E7, 7E8) to reddish brown (8E4) appressed squamules in almost concentric circles; margin initially incurved, becoming straight, initially entire, fissile with age. **Lamellae** free, initially whitish, turning yellowish white (2A2, 3A2, 3A3) to cream-coloured (4A3), crowded, up to 2 mm wide, with lamellulae in 2-3 tiers; edge finely fimbriate under a lens, concolorous with the sides. **Stipe** 12-27 x 1-3 mm (up to 5 mm at the base), central, terete, almost equal with a bulbous base, fistulose; surface brownish orange (7C4) to brown (7D8, 7E7, 7E8), squamulose, with squamules that are darker and concentrated more towards the base; base arising from white mycelial cords. **Annulus** superior, fibrillose, disrupted, evanescent. **Context** less than 1 mm thick, whitish to yellowish white (2A2, 3A2). **Odour** not distinctive. **Spore-print** white.

Spores 4.5-7 x 2.5-4 (5.5 ± 0.54 × 3 ± 0.54) µm, Q = 1.25-2, Qm = 1.7, oblong-ellipsoid to subcylindric, hyaline, with oil guttules, smooth, thin- to slightly thick-walled, dextrinoid, non-metachromatic in cresyl blue, cyanophilic in cotton blue. **Basidia** 14-19 x 5-7 µm, cylindrico-clavate to clavate, with guttulate contents, bearing 4 sterigmata up to 4 µm long.

Lamella-edge sterile or heteromorphous with abundant cheilocystidia. **Cheilocystidia** 10-25 x 4-9 µm, clavate, hyaline to pale yellow, thin-walled. **Pleurocystidia** absent. **Lamellar trama** subregular to somewhat irregular; hyphae 2-20 µm wide, inflated, hyaline, thin-walled, septate, inamyloid. **Subhymenium** cellular. **Pileal trama** interwoven; hyphae 2-20 µm wide, inflated, hyaline to pale yellow, thin-walled, inamyloid. **Pileal covering** a trichodermium with erect or ascending terminal elements; terminal elements 24-187 x 8-17 µm, cylindric to flexuose with a slightly tapering apex, thick-walled (up to 2 µm), with brown to dark brown plasmatic and membrane pigments. **Stipe covering** a highly disrupted cutis with frequent trichodermial transitions of ascending or erect, cylindric, flexuose, sub-fusoid or clavate terminal elements, 22-127 x 9-11 µm, thick-walled, with pale brown to brown plasmatic and wall pigment. Clamp-connections present on all hyphae.

Habitat: On soil among decaying leaf litter, solitary or scattered, mostly collected under coconut trees and *Heliconia*.

Known Distribution: USA

Collections examined — Calicut District, Puthiyangadi: 27 October 2003, AK7; 8 May 2004, AK22; 12 May 2004, AK22a; 13 May 2004, AK22b; 16 May 2004, AK22c; 18 May 2004, AK22d; 10 October 2004, AK130; Koyilandi: 27 October 2004, AK156; 3 November 2004, AK167; Peruvannamuzhi: 13 November 2004, AK193.

This species has a yellowish white to cream-coloured pileus with brown to reddish brown appressed squamules, a whitish to yellowish white lamellae, stipe covered with brownish squamules in broken girdles, small oblong-ellipsoid to cylindric spores and a trichodermial pileal covering with ascending or erect cylindric to flexuouse terminal elements. Owing to the oblong-ellipsoid to subcylindric spores and by the trichodermial nature of pileal covering, the collection is placed in the section *Ovisporae* (Lange) Kühner. The present collections have characters almost identical with the description of the holotype material of *L. brevipes* given by Smith (1965). They also agree with the description of that species based on the type and additional materials of the species from Florida by Akers & Sundberg (1998). The Kerala specimens however, had smaller basidiomata.

Lepiota citrophylla (Bereley & Broome) Saccardo *sensu* Dennis (1952) has a campanulate pileus, light olive brown squamules, spores with a truncate base, more or less cylindrical cheilocystidia and larger terminal elements of pileal covering. It is remarkable that the Trinidad collection of *L. citrophylla* and many of the present collections of *L. brevipes* from Kerala were both collected under *Heliconia* plants. *Lepiota citrophylla sensu* Pegler mainly differs from *L. brevipes* in having spurred spores. A close resemblance with *L. flavidocana* from the Lesser Antilles, originally described by Pegler (1983) is evident, but the relatively smaller spores of that species keeps the two apart. A distant similarity can be inferred with *L. xanthophylla* P.D. Orton, but it is a yellow species that differ by its slightly larger spore dimensions and very long elements of the pilial covering.

Lepiota citrophylloides described by Sathe and Kulkarni (1980) from south west India have spurred and larger spores and are characterized by pyriform to spathulate pileal elements. This species was previously known only from Florida, its type locality.

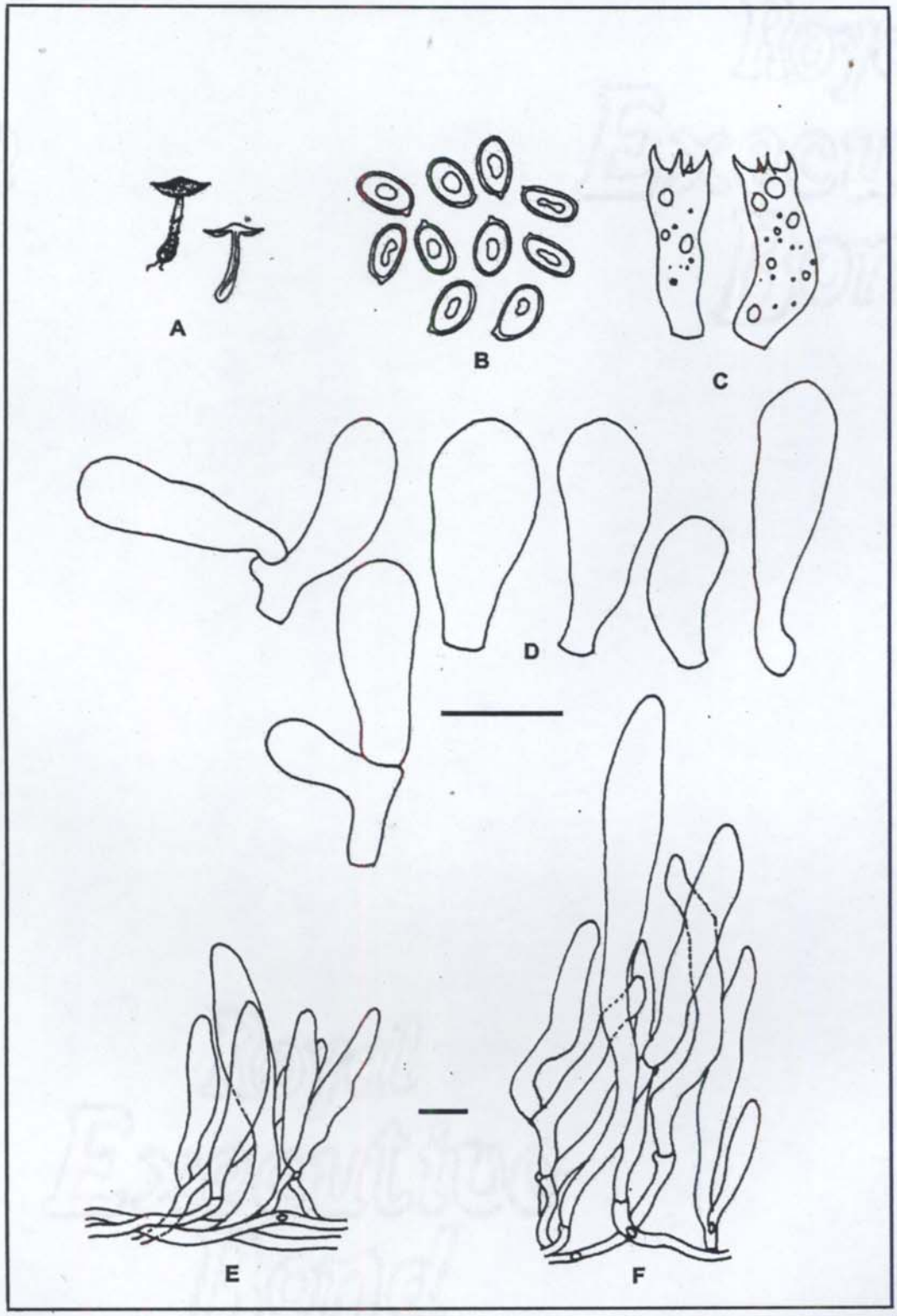


Figure10. *Lepiota brevipes* **A.** Habit x 1 **B.** Spores **C.** Basidia **D.** Cheilocystidia **E.** Stipe covering **F.** Pileus covering. Bars = 10 µm.

***Lepiota brevipes* variety 1**

Fig. 11. A-F; Pl. 10.

Basidiomata small. **Pileus** 11-16 mm diam., subglobose when young, becoming convex to broadly convex, finally applanate, with a broad umbo; surface whitish with reddish brown (8D6), appressed to recurved fibrillose squamules in broken, concentric circles that are concentrated towards the centre, pruinose at the disc, with an overall rosy tinge; margin initially incurved, later straight, appendiculate. **Lamellae** free, white, crowded, up to 2 mm wide, with lamellulae in 2-3 tiers; edge finely fimbriate under a lens, concolorous with the sides. **Stipe** 25-70 × 2-3 mm, central, terete, almost equal, with a subbulbous base, fistulose; surface whitish to brownish orange (7C5), usually more whitish approaching the apex, with reddish brown (8D6), scattered fibrillose scales that are lesser towards the upper portion and concentrated towards the base; base arising from white mycelial cords. **Annulus** as a disrupted fibrillose zone. **Context** less than 1 mm thick, whitish. **Odour** not distinctive. **Spore-print** not obtained.

Spores 4-5 × 3 (4.8 ± 0.31 × 3 ± 0) µm, Q = 1.3-1.7, Qm = 1.6, ovo-ellipsoid to ellipsoid or subcylindric, hyaline, with oil guttules, smooth, thin- to slightly thick-walled, dextrinoid, non-metachromatic in cresyl blue, cyanophilic in cotton blue. **Basidia** 14-18 × 6-7 µm, cylindrico-clavate to clavate, with guttulate contents, bearing 4 sterigmata up to 4 µm long. **Lamella-edge** sterile. **Cheilocystidia** 12-32 × 5.5-10 µm, cylindrical,

clavate, broadly clavate, utriform, some with median constriction, hyaline to pale yellow, slightly thick- to thick-walled (up to 1 µm), with amorphous exudates on the surface. **Pleurocystidia** absent. **Lamellar trama** subregular; hyphae 2-25 µm wide, inflated, hyaline, thin-walled, septate, inamyloid. **Subhymenium** cellular. **Pileal trama** interwoven; hyphae 2-20 µm wide, inflated, hyaline to pale yellowish, thin- to slightly thick-walled, inamyloid. **Pileal covering** a trichodermium with erect or ascending terminal elements; terminal elements 24-120 × 4-12 µm, mostly fusoid, rarely cylindric, clavate, flexuose, or lageniform, thick-walled (up to 1.5 µm), with brown to dark brown plasmatic and membrane pigments. **Stipe covering** a highly disrupted cutis with trichodermial patches of ascending or erect, cylindric, flexuose, fusoid, lageniform or clavate terminal elements 30-90 × 5-10 µm with thick walls and brown to dark brown plasmatic and wall pigment. All hyphae with clamp-connections.

Habitat: On soil and decaying leaf litter, solitary or in scattered groups.

Known Distribution: Only from the type locality.

Collections examined — Thiruvananthapuram District, Palode: 15 July 2005, AK354; 18 July 2005, AK354a; 20 July 2005, AK372; Kallar: 4 August 2006, AK434; Calicut District, Peruvannamuzhi: 25 September 2006, AK441.

This is a regularly fruiting agaric with an overall rosy tint. It differs from the typical variety mainly by the characters shown in Table 3:

Table 3: Character differences observed between the two *L. brevipes* varieties.

L. brevipes var. *brevipes*	*L. brevipes* variety 1
1) Fruiting solitary	1) Solitary or in scattered groups
2) Basidiomata small	2) Basidiomata larger and robust
3) Reddish brown squamules on a yellowish white, pale yellow/ cream background	3) On a whitish background
4) Pileal margin entire	4) Margin appendiculate
5) Lamellae initially whitish turning yellowish white to cream-coloured	5) Lamellae white
6) Context whitish to yellowish white	6) Context whitish
7) Cheilocystidia thin-walled, without any encrustations, more or less cylindrical to clavate	7) Cheilocystidia slightly thick- to thick-walled, with amorphous encrustations, cylindric, clavate, broadly clavate, utriform

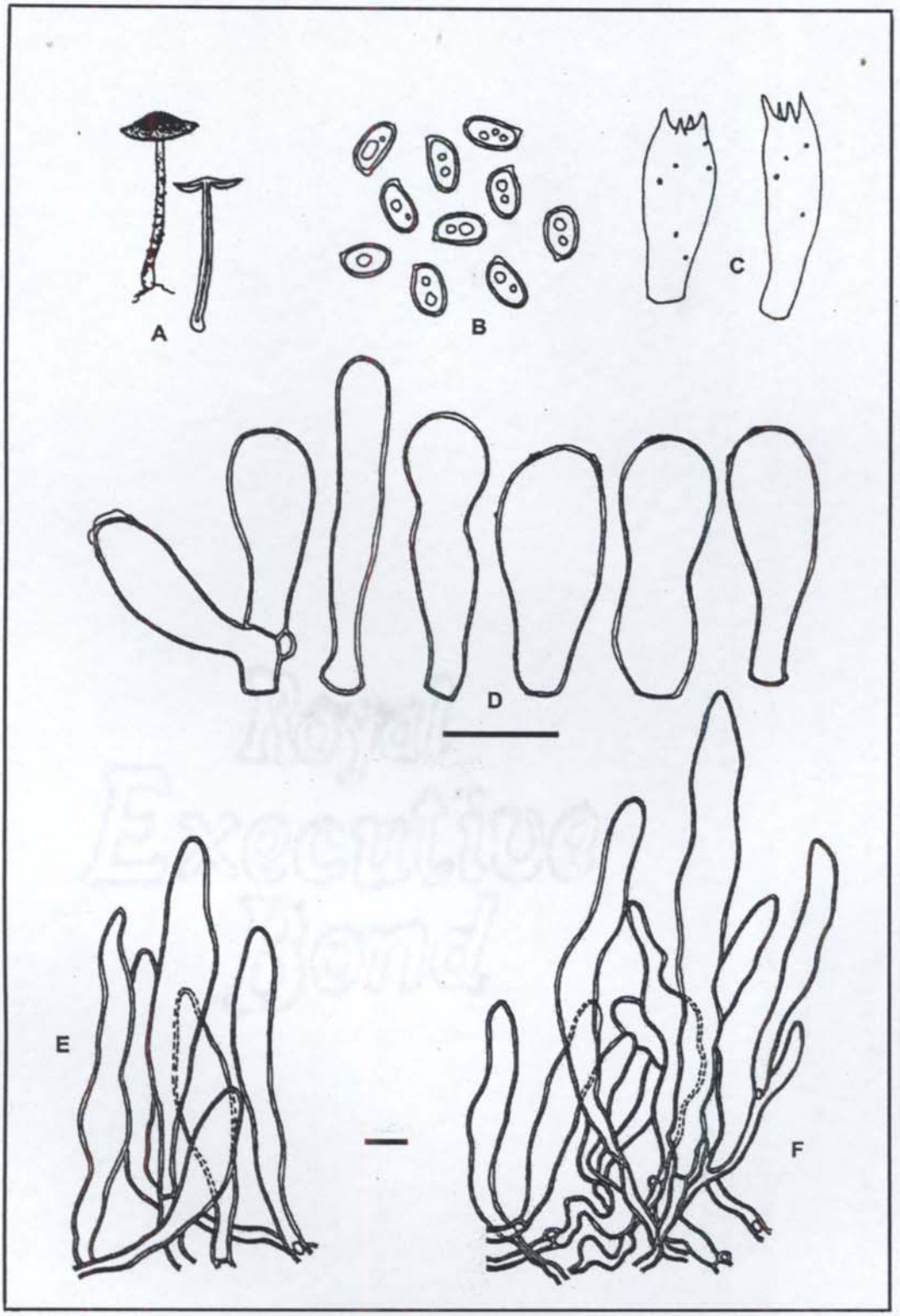


Figure 11. *Lepiota brevipes* var. 1 **A.** Habit x 1 **B.** Spores **C.** Basidia **D.** Cheilocystidia **E.** Stipe covering **F.** Pileus covering. Bars = 10 µm.

Plate 9. *Lepiota brevipes* x 5

Plate 10. *Lepiota brevipes* variety 1 x 4

Lepiota xanthophylla Orton in Transactions of the British Mycological Society 43: 289 (1960)

Fig. 12. A-F; Pl. 11.

Basidiomata small. **Pileus** 22-25 mm diam., initially broadly convex, finally applanate, umbonate at the disc; surface greyish yellow (4B4), with olive brown (4E4, 4F8) appressed fibrillose squamules in broken concentric circles, squamules concentrated towards the disc which appear somewhat pruinose to scabrous; margin initially incurved, later straight, extending beyond the lamellae, eroded. **Lamellae** free, pastel yellow (2A4), crowded, up to 3 mm wide, with lamellulae in 2-3 tiers; edge finely fimbriate under a lens, concolorous with the sides. **Stipe** 25-30 × 2-2.5 mm, central, terete, equal with a bulbous base, initially solid, becoming fistulose with age; surface pale yellow (1A3) to pastel yellow (2A4), covered with olive brown (4F8) to brown (6E5) squamules; base arising from a white mycelium. **Annulus** present as a discrete fibrillose-zone on the upper portion of the stipe. **Context** up to 1.5 mm thick, pastel yellow (2A4). **Odour** not distinctive. **Spore-print** not obtained.

Spores 6-8 × 3-4.5 (6.8 ± 0.63 × 3.8 ± 0.44) µm, Q = 1.5-2.3, Qm = 1.8, mostly ellipsoid, rarely amygdaliform, slightly thick-walled, hyaline, with refractive guttules, smooth, dextrinoid, non-metachromatic in cresyl blue, cyanophilic in cotton blue. **Basidia** 14-17 × 5-7 µm, clavate, hyaline to pale yellowish, with guttulate contents, bearing 4 sterigmata up to 3 µm long. **Lamella-edge** sterile. **Cheilocystidia** crowded, 17-48 × 6-14 µm, cylindrical,

clavate or utriform, mostly septate or segmented and at times branched, thin-walled, hyaline to pale yellowish. **Pleurocystidia** absent. **Lamellar trama** subregular; hyphae 2-26 µm wide, inflated, thin-walled, hyaline, inamyloid. **Subhymenium** cellular. **Pileal trama** interwoven, hyphae 2-10 µm wide, inflated up to 30 µm, thin-walled, hyaline to pale yellowish, inamyloid. **Pileal covering** a cutis disrupted by trichodermial patches of ascending or erect terminal elements, increasingly trichodermial with slightly agglutinated hyphae towards the disc; terminal elements 28-300 × 8-17 µm, clavate or fusoid, rarely branched, thick-walled (up to 1 µm) with yellowish brown to grey plasmatic and membrane pigments, smaller elements (perhaps younger ones) invariably clavate (which presumably matures to become longer, fusoid cells). **Stipe covering** a disrupted cutis made of 2-27 µm wide hyphae, with occasional ascending or erect terminal elements; terminal elements 32-232 × 8-15 µm, thick-walled and with brownish to grey plasmatic and membrane pigments. Clamp-connections present.

Habitat: On soil among decaying leaf litter, solitary or scattered.

Known Distribution: EUROPE, AFRICA, Japan

Collections examined — Malappuram District, Calicut University Campus: 9 July 2005, AK346; 12 July 2005, AK349.

Lepiota xanthophylla is a yellow species with ellipsoid spores. It is known in European countries only from green houses and not from natural habitats, thereby indicating its tropical origin as mentioned by Vellinga & Huijser (1997). The present collections agree with the description of the species given by Orton (1960), Vellinga & Huijser (1997) and Vellinga (2001a). It differs from the closely related *Lepiota elaiophylla* Vellinga & Huijser mainly by the presence of numerous short clavate cells along with the long cylindrical elements in the pileus covering and by the cheilocystidia which are mostly narrowly lageniform to narrowly utriform. This will be the first record of the species from India.

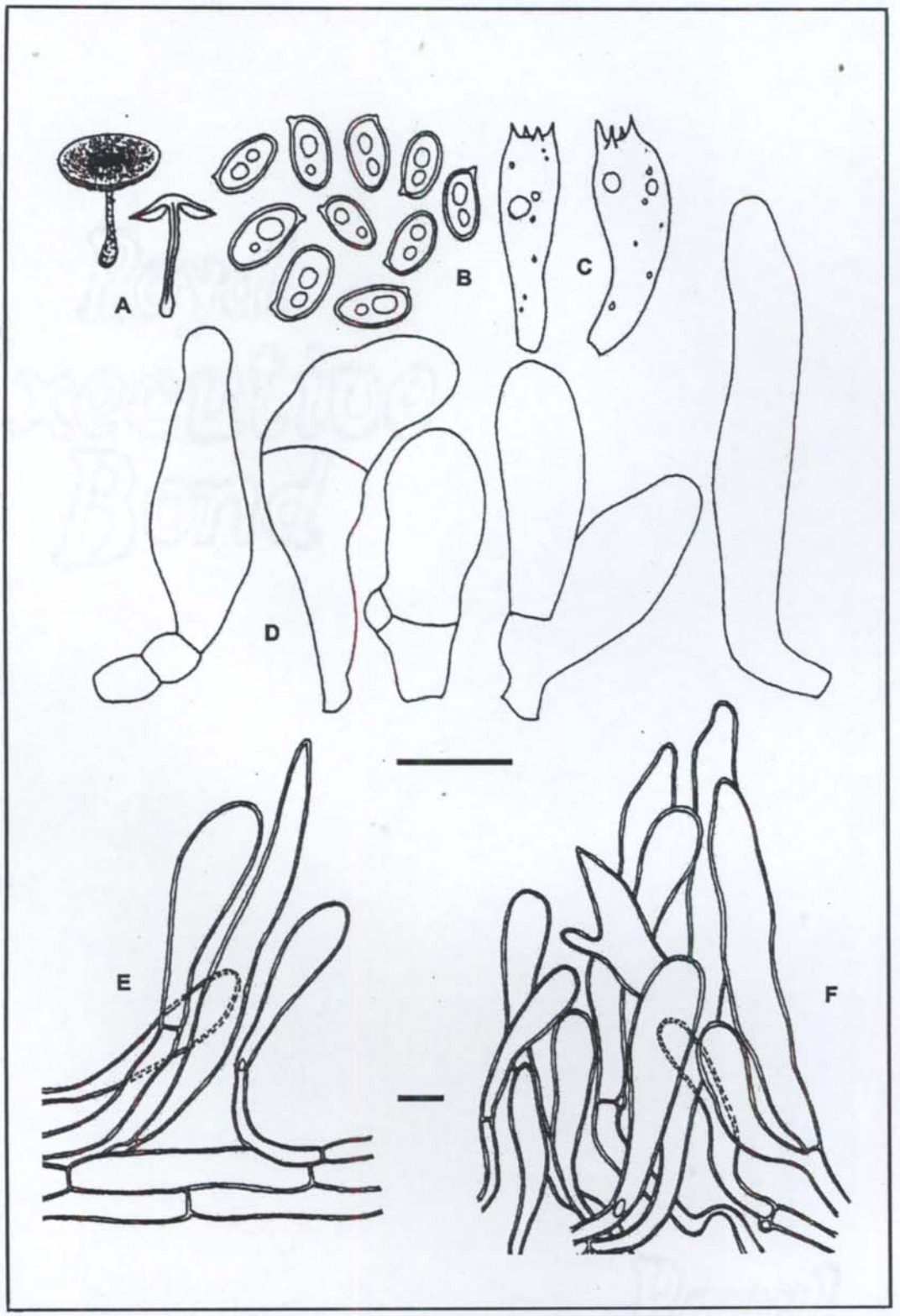


Figure 12. *Lepiota xanthophylla* **A.** Habit x 1 **B.** Spores **C.** Basidia **D.** Cheilocystidia **E.** Stipe covering **F.** Pileus covering. Bars = 10 µm.

Lepiota elaiophylla Vellinga & Huijser in Bolletino Del Gruppo Micologico G. Bresadola 40:457-464 (1997)

Fig. 13. A-F; Pl. 12.

Basidiomata small to somewhat medium-sized. **Pileus** 10-36 mm diam., globose when very young, becoming broadly convex and finally applanate on maturity, broadly umbonate; surface yellowish white (1A2) to pale yellow (3A3), furfuraceous, with light brown (6D4, 6D5) to brown (6E5) fibrillose squamules that are sparser and appressed towards margin and concentrated and recurved towards the centre giving a slightly scabrous appearance; pileal covering easily peeling off as a layer; margin appendiculate, initially incurved becoming straight and fissile with age. **Lamellae** free, pastel yellow (1A4, 1A5, 2A4, 2A5), moderately crowded to crowded, thin, up to 6 mm wide, with lamellulae in 2-3 tiers; edge finely fimbriate under a lens, concolorous with the sides. **Stipe** 23-50 × 2-5 mm, central, terete, almost equal with a more or less expanded base, fistulose becoming hollow; surface fibrillose, concolorous with the pileus with light brown (6D4) to brown (6E5) squamules forming zonations, yellowish brown (5E6) to dark brown on bruising; base arising from white mycelial cords. **Annulus** superior, fibrillose-zonate, descending, rarely distinct in older specimens. **Context** less than 3 mm thick, pastel yellow (1A4, 1A5) to pale yellow (3A3). **Odour** somewhat unpleasant. **Spore-print** white to yellowish white (2A2).

Spores 6-9 × 3-4.5 (6.5 ± 0.43 × 3.8 ± 0.34) µm, Q = 1.5-2, Qm = 1.71, oblong, subcylindric or ellipsoid, thin- to slightly thick-walled, hyaline, with refractive guttules, smooth, dextrinoid, non-metachromatic in cresyl blue, cyanophilic in cotton blue. **Basidia** 15-27 × 6-8 µm, clavate, with guttulate contents, bearing 4 sterigmata up to 5 µm long. **Lamella-edge** sterile. **Cheilocystidia** abundant, 12-43 × 4-11 µm, clavate or cylindric with obtuse tips or rarely mucronate, thin-walled, hyaline. **Pleurocystidia** absent. **Lamellar trama** subregular; hyphae 2-8 µm wide, inflated up to 20 µm, thin-walled, hyaline, inamyloid. **Subhymenium** cellular. **Pileal trama** interwoven, made of septate, 3-15 µm wide, inflated, thin-walled, hyaline, inamyloid hyphae. **Pileal covering** a trichodermium towards the centre and a disrupted cutis towards margin, with ascending or erect bundles of cylindric or fusiform elements, 20-350 × 7-20 µm, with obtuse, acuminate or acute apices, with brown plasmatic as well as membrane pigments, and a wall up to 1 µm thick. **Stipe covering** a disrupted cutis or trichodermium with ascending, cylindrical or fusiform end-cells, 38-256 × 5-18 µm, pale brown to brown pigmented, with a thin- to slightly thick-wall. All hyphae with abundant clamp-connections.

Habitat: On soil and decaying leaf litter, solitary and scattered.

Known Distribution: EUROPE.

Collections examined — Calicut District, Koyilandy: 27 October 2004, AK154; 3 November 2004, AK154a; 3 November 2004, AK168; 20 November 2004, AK154b; 13 October 2006, AK456; Malappuram District, Calicut University Campus: 8 June 2005, AK239; 9 June 2005, AK239a; 21 June 2005, AK281.

This yellow *Lepiota* species has characters that match with the original description of *Lepiota elaiophylla*. Vellinga & Huijser (1997) distinguish this species from *L. xanthophylla* P. D. Orton primarily by the lack of a layer of clavate short elements in-between the cylindric to fusiform terminal elements. Till now the species has only been reported from green houses in Europe. This forms the first record from a tropical region.

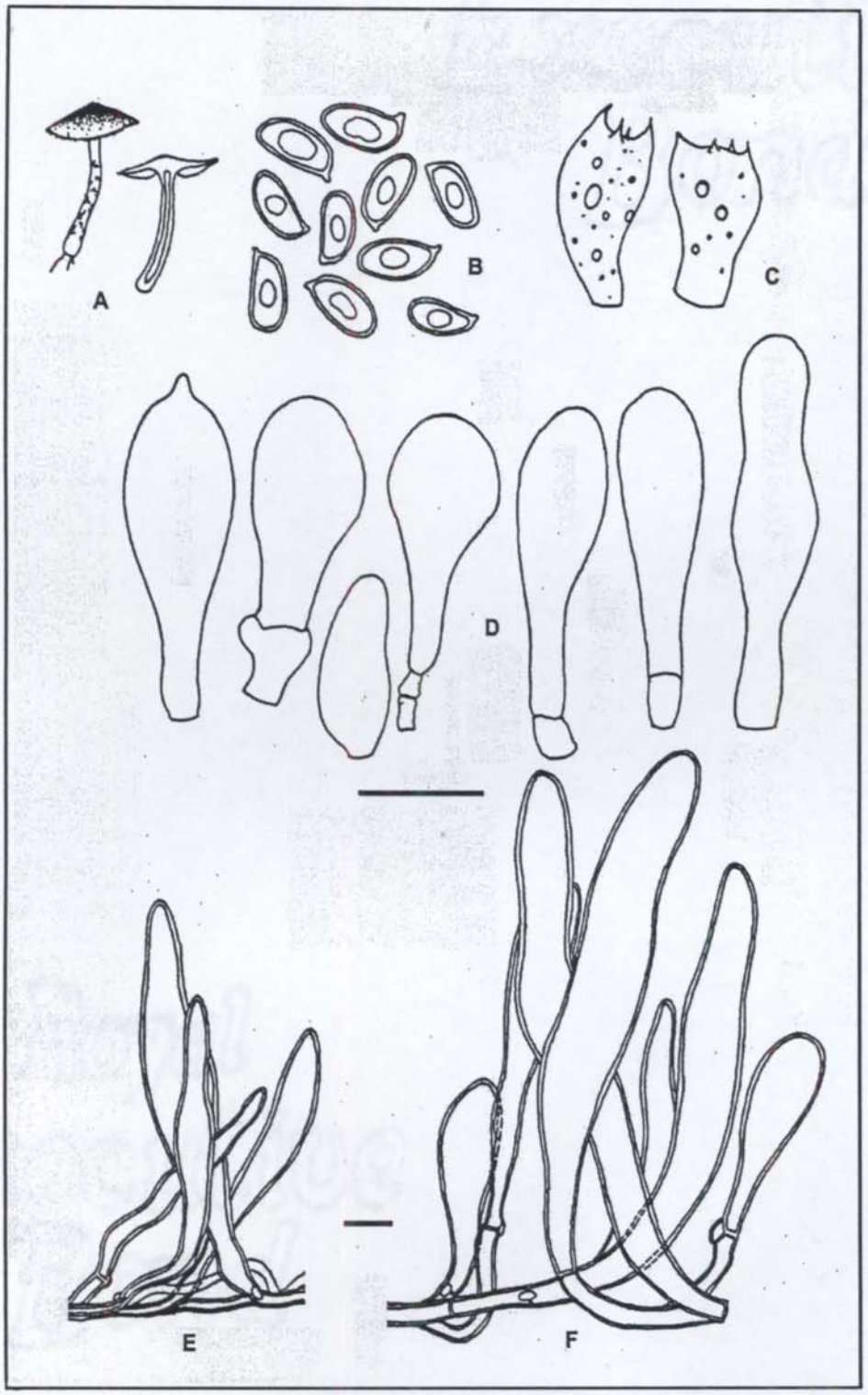


Figure 13. *Lepiota elaiophylla* **A.** Habit x 1 **B.** Spores **C.** Basidia **D.** Cheilocystidia **E.** Stipe covering **F.** Pileus covering. Bars = 10 µm.

Plate 11. *Lepiota xanthophylla* x 4.5

Plate 12. *Lepiota elaiophylla* x 2.5

Lepiota ianthinosquamosa Pegler in Kew Bulletin Additional Series. 9: 389 (1983)

Fig. 14. A-F; Pl. 13.

Basidiomata medium-sized. **Pileus** 42-45 mm diam., initially convex, becoming broadly convex to applanate on maturity, broadly umbonate; surface whitish with large, appressed, dark grey (16F1) squamules that are denser towards the disc; margin incurved when young, becoming straight on maturity, appendiculate. **Lamellae** free, whitish, close to moderately crowded, up to 5 mm wide, with lamellulae in 3 tiers; edge finely fimbriate under a lens, concolorous with the sides. **Stipe** 32-62 × 4-5 mm, central, terete, almost equal, slightly expanded or almost bulbous at the base, fistulose becoming hollow with age; surface whitish to dull white, turning brown (6E4) on bruising, dark grey (16F1) below the annulus, fibrillose above the annulus, thickly squamulose below annulus; base arising from white mycelial cords. **Annulus** superior, white with a dark grey (16F1) rim, membranous, movable, evanescent. **Context** up to 2 mm thick, whitish. **Odour** unpleasant. **Spore-print** not obtained.

Spores 6-9 × 3-4 (5) (7.8 ± 0.77 × 4 ± 0.44) µm, Q = 1.7-2.25, Qm = 1.9, lacrymoid to subcylindric with a strong suprahilar depression, hyaline, with refractive guttules and a thin- to slightly thick wall, smooth, dextrinoid, non-metachromatic in cresyl blue, cyanophilic in cotton blue. **Basidia** 20-27 × 6-8 µm, clavate, with guttulate contents, bearing 4 sterigmata up to 7 µm long. **Lamella-edge** sterile with crowded cheilocystidia. **Cheilocystidia** 14-

27 × 6-14 µm, broadly clavate, rarely subfusoid or somewhat mucronate, thin-walled, hyaline. **Pleurocystidia** absent. **Lamellar trama** broad, subregular to somewhat irregular; hyphae 2-13 µm wide, some times inflated up to 22 µm, hyaline, thin-walled, septate, branched, inamyloid and with obtuse tips. **Subhymenium** cellular. **Pileal trama** interwoven; hyphae 2-7 µm wide, inflated up to 15 µm, hyaline, thin-walled, inamyloid. **Pileal covering** a strongly developed trichodermium formed of chains of cylindric or clavate cells; terminal elements 26-111 × 5-15 µm, slightly thick- to thick-walled and with violaceous to dark grey plasmatic pigment. **Stipe covering** a disrupted cutis with trichodermial patches, with 20-88 × 8-15 µm large, thin- to slightly thick-walled, dark grey pigmented clavate to cylindrical terminal elements. All hyphae with abundant clamp-connections.

Habitat: On soil among decaying leaf litter, solitary or scattered,

Known Distribution: The Lesser Antilles

Collections examined — Calicut District, Peruvannamuzhi: 13 November 2004, AK195; 22 July 2004, AK195a.

The macro and microscopic characters of the present collection agrees well with Pegler's (1983) description of the species from a xero-mesophytic forest in the Lesser Antilles, except for the slightly smaller spores and larger pileal elements. The character combinations place the

species in the section *Ovisporae* (Lange) Kühner. A distant similarity with *L. fuscovinacea* Moller & Lange is seen with regard to the macroscopic characters, but *L. ianthinosquamosa* clearly differs in the darker fruit bodies, larger and distinct lacrymoid spores and in the presence of clamp-connections. *Lepiota ianthinosquamosa* has so far been reported only from the Lesser Antilles.

Lepiota viriditincta (Berkeley & Broome) Saccardo in Sylloge Fungorum 5: 59 (1887)

Agaricus viriditinctus Berkeley & Broome in Journal of the Linnean Society Botany 11: 503 (1871)

Agaricus pyrocephalus Berkeley & Broome in Journal of the Linnean Society Botany 11: 504 (1871)

Lepiota pyrocephalus (Berkeley & Broome) Saccardo in Journal of the Linnean Society Botany 11: 60 (1887)

Fig. 15. A-E; Pl. 14.

Basidiomata small, turning greyish green (25D6, 25E6) on touch, bruising or on drying. **Pileus** 6-10 mm diam., initially convex, becoming applanate with a slightly umbonate disc; surface white, covered with brown (7E7, 7F7) appressed squamules which are more concentrated towards the centre giving a pruinose appearance to the disc, finely striate towards the margin; margin incurved, becoming straight, appendiculate. **Lamellae** free, white, becoming greyish green (25D6, 25E6) on touch or on drying, crowded, less than 2 mm wide, with lamellulae in 2-3 tiers; edge entire to finely fimbriate under a lens, concolorous with the sides. **Stipe** 20-42 × 1-2 mm, central, terete, initially solid, becoming fistulose to hollow, with a slightly expanded base; base arising from white mycelial cords; surface longitudinally fibrillose, white, turning greyish green (25D6-25E6) on bruising or on drying. **Annulus** superior, membranous, simple, movable, evanescent. **Context** less than 1 mm thick, white, changing to greyish green (25D6-25E6) with touch, bruising or on drying. **Odour** not distinctive. **Spore-print** white.

Spores 7-10 × 4-5 (8 ± 0.77 × 4.8 ± 1.7) µm, Q = 1.4-2, Qm = 1.7, mostly amygdaliform, rarely oblong-ellipsoid, thin- to slightly thick-walled, smooth, hyaline, with guttulate contents, dextrinoid, non-metachromatic in cresyl blue, cyanophilic in cotton blue. **Basidia** 14-24 × 8-9 µm, obovoid to clavate, thin-walled, hyaline, bearing 4 sterigmata up to 4.5 µm long. **Lamella-edge** fertile. **Cheilocystidia** absent. **Pleurocystidia** absent. **Lamellar trama** subregular, of highly inflated, 3-27 µm wide, thin-walled, hyaline to pale green, inamyloid. **Subhymenium** cellular. **Pileal trama** subregular to interwoven; composed of 2-27 µm wide, septate, hyaline, branched, thin-walled, inamyloid hyphae. **Pileal covering** a disrupted cutis of repent or ascending hyphae becoming almost trichodermial towards the disc; terminal elements 18-82 × 7-19 µm, cylindric to clavate with obtuse apices, thin-walled, with brown plasmatic and encrusting pigments. **Stipe covering** a cutis; hyphae with cylindric or clavate 21-34 × 5-7 µm, ascending or repent, hyaline or pale brown pigmented terminal elements. Clamp-connections very rare, observed on hyphae of lamellar trama.

Habitat: On soil among decaying leaf litter, scattered,

Known Distribution: Brazil, Sri Lanka, India

Collections examined — Malappuram District, Calicut University Campus: 9 November 2004, AK177; 9 November 2004, AK180; 10 November 2004, AK177a; 27 June 2005, AK319.

This is an interesting small species that exhibit greyish green colour change with touch or on bruising on all parts of the basidiomata. It has a white pileus covered with minute brown squamules and finely striate towards the margin, an evanescent annulus, amygdaliform spores and a pileal covering disrupted by trichodermial cylindric to clavate terminal elements with brown plasmatic and encrusting pigments.

Characters of the present collections agree well with those of the species provided by Manimohan *et al.* (1988) from Kerala and by Pegler (1972, 1986) from Sri Lanka (based on holotype at Kew) except for the somewhat smaller basidiomata and slightly larger spores. The lamella-edge was not recovered from the Sri Lankan material Pegler studied and hence details on the cheilocystidia are lacking in his description. Manimohan *et al.* (1988) also noted the absence of cystidia in their collections from Kerala. Similarly, the present collections from Kerala too, did not show cheilocystidia in any of the specimens.

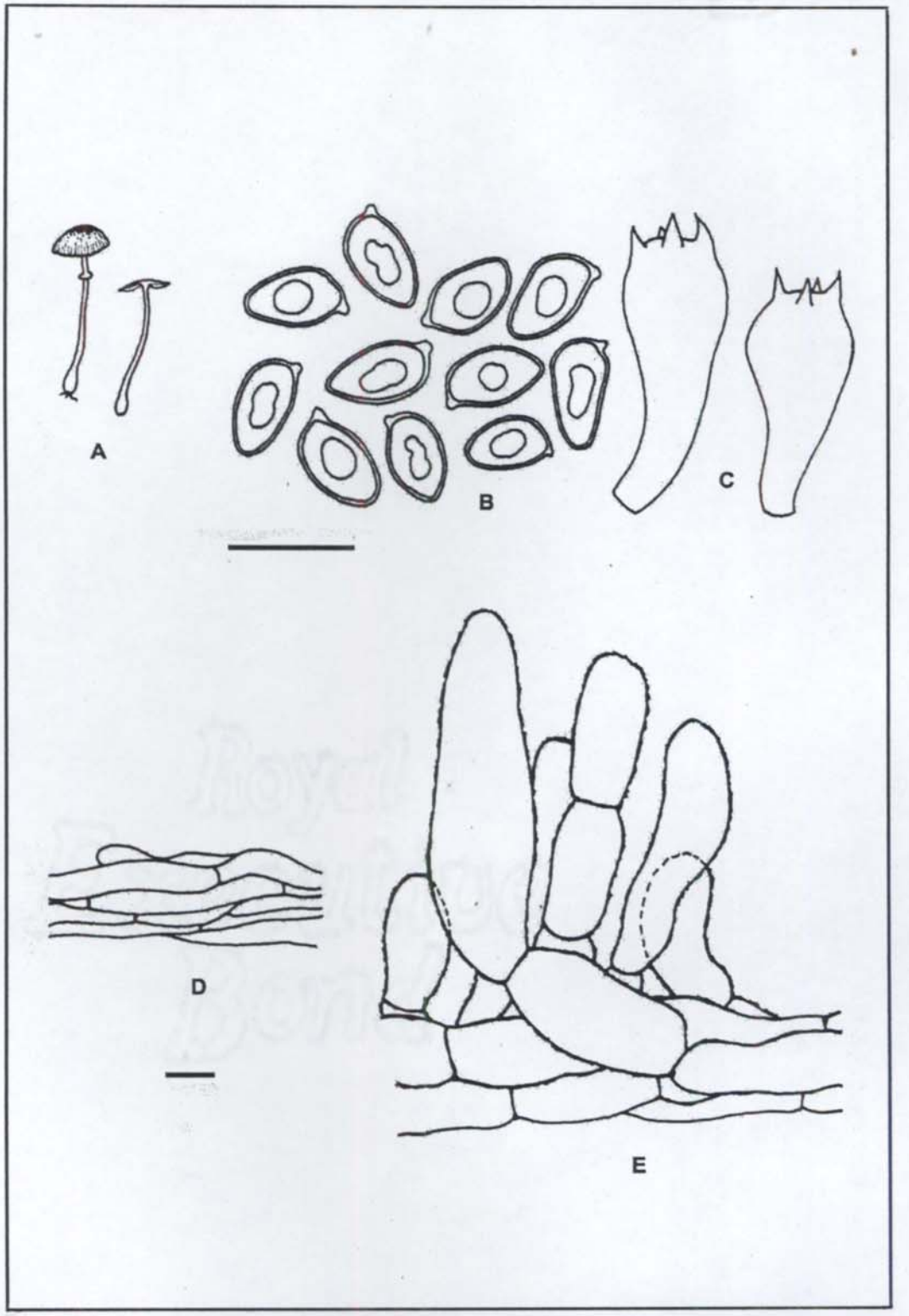


Figure 15. *Lepiota viriditincta* **A.** Habit x 1 **B.** Spores **C.** Basidia **D.** Stipe covering **E.** Pileus covering. Bars = 10 µm.

Plate 13. *Lepiota ianthinosquamosa* x 3

Plate 14. *Lepiota viriditincta* x 5

***Lepiota* species 1**

Fig. 16. A-F; Pl. 15.

Basidiomata small. **Pileus** 15-20 mm diam., initially convex, becoming campanulate to broadly convex, applanate on maturity, obtusely umbonate at the disc; surface whitish with brownish grey (8F2, 11E2, 11F2) to reddish grey (12F2) flaky squamules concentrated more towards the disc, finely sulcate-striate towards margin; margin incurved, becoming straight, entire, becoming fissile with age. **Lamellae** free, white, crowded, up to 2.5 mm wide, with lamellulae in 2-3 tiers; edge finely fimbriate under a lens, concolorous with the sides. **Stipe** 23-40 × 2-3 mm (up to 5 mm at base), central, terete, almost equal above the annulus, expanding towards the base, solid when young, becoming hollow; surface whitish, almost glabrous to slightly fibrillose; base arising from a white mycelium. **Annulus** superior, membranous, ascending, fixed. **Context** less than 1 mm thick, white. **Odour** not distinctive. **Spore-print** white.

Spores 5-7 × 3.5-5 (5.7 ± 0.4 × 4 ± 0.2) µm, Q = 1.25-1.5, Qm = 1.44, oblong-ellipsoid to broadly ellipsoid, hyaline, with refractive guttules, thick-walled, smooth, dextrinoid, non-metachromatic in cresyl blue, cyanophilic in cotton blue. **Basidia** 14-20 × 7-10 µm, clavate, rarely broadly clavate, with guttulate contents, bearing 4 sterigmata up to 3 µm long. **Lamella-edge** sterile. **Cheilocystidia** 20-59 × 6-15 µm, cylindrico-clavate to cylindric-flexuose, rarely with a subcapitate apex, hyaline, thin-walled. **Pleurocystidia** absent. **Lamellar trama** subregular; hyphae 3-31 µm wide, inflated, septate,

hyaline, thin-walled, inamyloid. **Subhymenium** cellular. **Pileal trama** interwoven; hyphae 2-22 µm wide, hyaline, thin-walled, septate, inamyloid. **Pileal covering** a cutis of filamentous repent hyphae disrupted by trichodermial patches of agglutinated hyphal bundles with cylindrical, clavate or ellipsoid, 12-65 × 5-12 µm large, thin- to slightly thick-walled terminal elements with obtuse or acuminate tips and dense brownish grey to dark grey plasmatic pigment. **Stipe covering** a cutis of 3-15 µm wide, hyaline, thin-walled hyphae with cylindrical, 22-43 × 5-8 µm large terminal elements. Clamp-connections rare, observed only from hyphae of the pileal covering.

Habitat: On humus rich soil, solitary or scattered.

Known Distribution: Only from the type locality.

Collections examined — Calicut District, Puthiyangadi: 12 November 2003, AK13; 14 November 2003, AK13a; 17 August 2004, AK91; Kolamala: 19 July 2006, AK420; Malappuram District, Calicut University Campus: 24 May 2004, AK33; 26 May 2004, AK33a; 26 May 2004, AK38; 6 June 2005, AK234; 26 June 2006, AK400; 20 November 2006, AK460.

A white pileal surface with scattered flaky squamules and finely striate margin, a fixed membranous annulus, oblong-ellipsoid to broadly ellipsoid spores, and a pileal covering that is basically a cutis disrupted by trichodermial patches, with cylindrical, clavate or ellipsoidal terminal

elements are the major distinguishing features of this species. Characters of this species do not exactly match with those of any of the known taxa. It is somewhat similar to *Lepiota columbicolor* (Berkeley & Broome) Saccardo as described by Pegler (1972, 1986). However, *L. columbicolor* differs from the Kerala material because of the following characteristics: 1) lead greyish pileal and stipe surface; 2) pink lamellae with brownish edge; 3) grey context; 4) less broader spores with slight apical attenuation; 5) cheilocystidia with greyish plasmatic pigments; and 6) an entirely cutis-type pileal covering. Except for its vinaceous cinnamon stipe, an annulus which is coloured dark purplish grey beneath, and its squamular composition which is a hymeniform layer of clavate terminal cells, *L. lilacea* Bresadola from Venezuela (Dennis 1961), macroscopically somewhat resemble the present species

This species is very common in the Calicut and Malappuram Districts of Kerala and has been observed to fruit immediately on the onset of monsoon. Fruiting continues for about one and a half weeks and gradually stops with increasing rainfall.

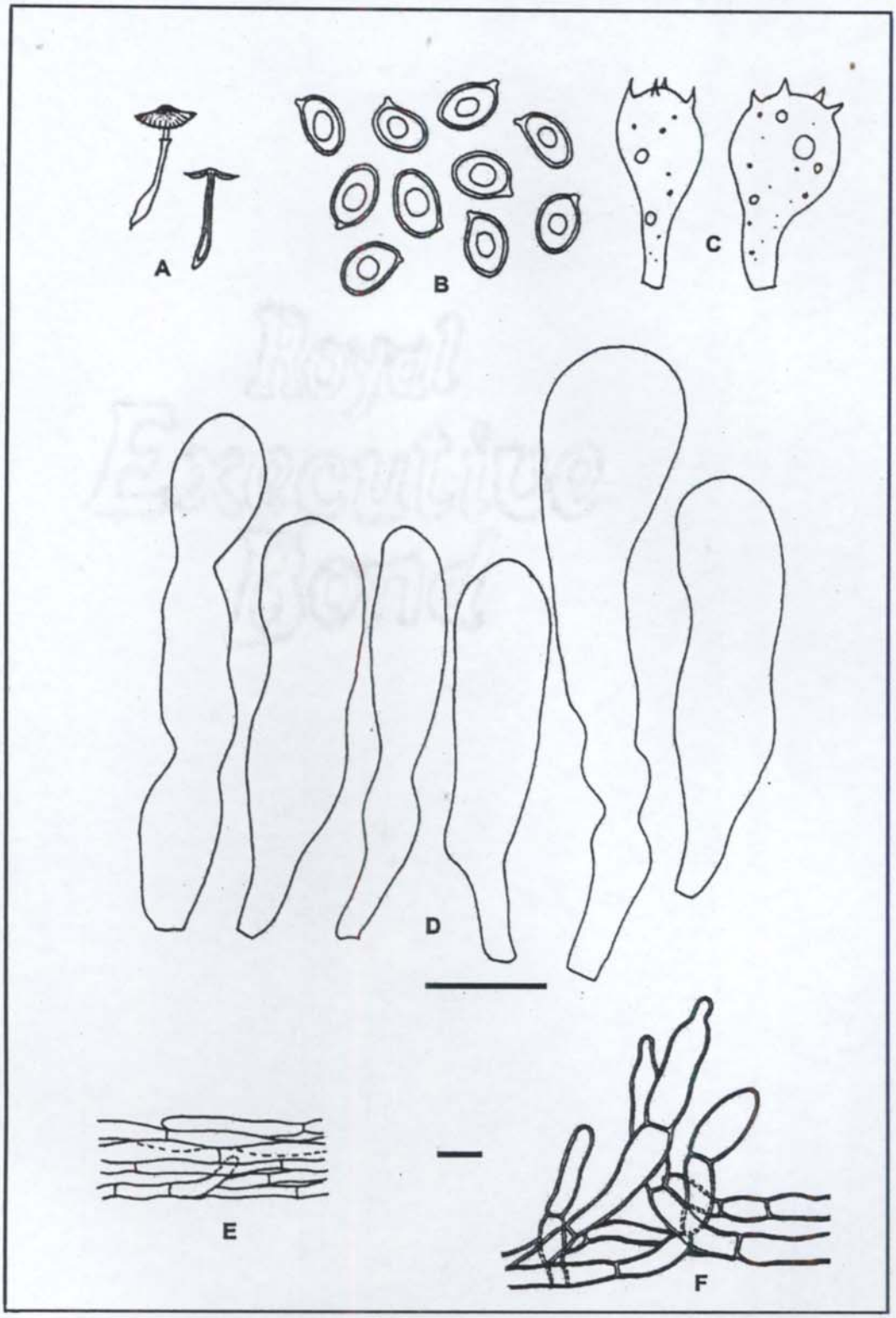


Figure 16. *Lepiota* species 1 **A.** Habit x 1 **B.** Spores **C.** Basidia **D.** Cheilocystidia **E.** Stipe covering **F.** Pileus covering. Bars = 10 µm.

***Lepiota* species 6**

Fig. 17. A-F; Pl. 16.

Basidiomata small. **Pileus** 14-25 mm diam., initially convex, becoming broadly convex and finally applanate, distinctly umbonate at the disc; surface whitish, sometimes with a yellowish tinge, with dark brown (8F8) appressed fibrillose squamules more concentrated towards the centre, almost smooth at the disc, finely striate towards the margin; margin initially incurved, later straight, crenate. **Lamellae** free, pale yellow (2A2) to light yellow (3A5), crowded, up to 3 mm wide, with lamellulae in 3-4 tiers; edge fimbriate under a lens, concolorous with the sides. **Stipe** 22-40 × 1.5-5 mm, central, terete, expanding towards base, initially fistulose, becoming hollow; surface whitish, fibrillose; base arising from a white mycelium. **Annulus** superior, membranous, ascending. **Context** up to 2 mm thick, whitish to pale yellow (2A2). **Odour** not distinctive. **Spore-print** not obtained.

Spores 5.5-8 × 3.5-4.5 (5.7 ± 0.9 × 4 ± 0.22) µm, Q = 1.3-2, Qm = 1.6, amygdaliform, thick-walled (up to 1 µm), hyaline, with refractive guttules, smooth, dextrinoid, non-metachromatic in cresyl blue, cyanophilic in cotton blue. **Basidia** 13-21 × 8-10 µm, clavate, some broadly clavate, hyaline, with guttulate contents, bearing 4 sterigmata up to 5 µm long. **Lamella-edge** sterile. **Cheilocystidia** crowded, 15-37 × 7.5-10 µm, cylindrical, clavate, or utriform, some septate, rarely constricted, thin-walled, hyaline or pale yellowish. **Pleurocystidia** none. **Lamellar trama** subregular; hyphae 2-17

µm wide, thin-walled, hyaline to pale yellow, inamyloid. **Subhymenium** cellular. **Pileal trama** interwoven; hyphae 2-17 µm wide, cylindrical, thin-walled, hyaline to pale yellowish, inamyloid. **Pileal covering** a cutis of interwoven filamentous hyphae, with occasional ascending or erect terminal elements; hyphae 3-14 µm wide, thin- to slightly thick-walled and with brown to dark grey plasmatic, membrane and encrusting pigments. **Stipe covering** a cutis of repent, cylindrical, 2-10 µm wide, thin-walled, hyaline hyphae. Clamp-connections rare.

Habitat: On decaying leaf litter, solitary or scattered.

Known Distribution: Only from the type locality.

Collections examined — Thiruvananthapuram District, Palode: 15 July 2005, AK351;

Yellowish lamellae, amygdaliform spores, a cutis-type pileal covering composed of cylindrical hyphae with brown to dark grey plasmatic, membrane and encrusting pigments and rare clamp-connections makes the species unique.

Lepiota epicharis (Berkeley & Broome) Saccardo seems to be very close to the present species except for the pileal covering which is a disrupted epithelium of inflated clavate or pyriform elements in that species.

Since no other matching description could be found, the present species is suspected to be new to science.

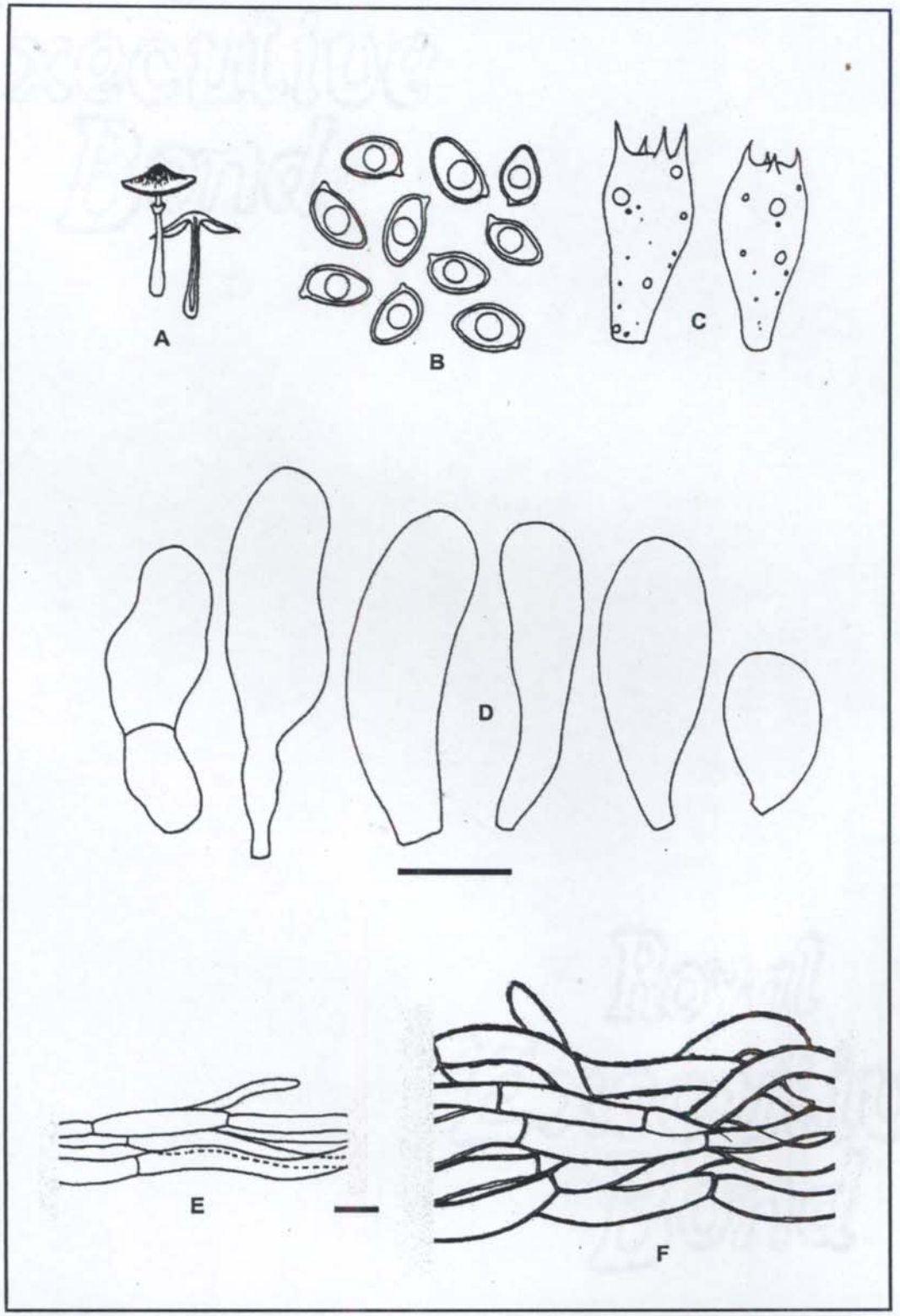


Figure 17. *Lepiota* species 6 **A.** Habit x 1 **B.** Spores **C.** Basidia **D.** Cheilocystidia **E.** Stipe covering **F.** Pileus covering. Bars = 10 µm.

Plate 15. *Lepiota* species 1 x 5.5

Plate 16. *Lepiota* species 6 x 3

***Lepiota* species 4**

Fig. 18. A-F; Pl. 17.

Basidiomata small. **Pileus** 10-13 mm diam., subglobose when young, becoming broadly convex to applanate, obtusely umbonate at the disc; surface dull white with scattered, minute, appressed, reddish brown (8E5, 8E6) squamules that are concentrated at the disc, non-striate; margin initially incurved, becoming straight, appendiculate. **Lamellae** free, white, turning orange white (5A2) on maturity, crowded, up to 2 mm wide, with lamellulae in 2-3 tiers; edge finely fimbriate under a lens, concolorous with the sides. **Stipe** 26-45 × 1-1.5 mm, central, terete, almost equal with a bulbous base, initially solid, becoming fistulose; surface dull white, becoming light brown (7D7) on bruising, faintly fibrillose. **Annulus** superior, membranous, ascending, movable, evanescent. **Context** less than 1 mm thick, whitish to dull white. **Odour** not distinctive. **Spore-print** white.

Spores 5.5-10.5 × 3.5-4.5 (7.5 ± 0.97 × 4 ± 0.23) µm, Q = 1.4-2.4, Qm = 1.9, oblong-ellipsoid, subcylindric, or rarely subamygdaliform, hyaline, with refractive guttules, thick-walled, smooth, dextrinoid, non-metachromatic in cresyl blue, cyanophilic in cotton blue. **Basidia** 15-20 × 7-8 µm, clavate, with guttulate contents, hyaline, 1-4-spored; sterigmata up to 8 µm long. **Lamella-edge** sterile. **Cheilocystidia** abundant, 13-32 × 7-12 µm, mostly cylindrico-clavate to clavate, rarely broadly clavate, utriform or ventricose-rostrate, occassionally septate, hyaline. **Pleurocystidia** absent. **Lamellar**

trama subregular; hyphae 3-15 µm wide, inflated, septate, thin-walled, hyaline to pale yellow, inamyloid. **Subhymenium** cellular, prominent, up to 10 µm wide. **Pileal trama** interwoven; hyphae 2-25 µm wide, inflated, hyaline, thin-walled, inamyloid. **Pileal covering** a differentiated, disrupted cutis becoming more or less trichodermial towards the disc; terminal elements 13-31 × 4-7 µm, cylindrical or clavate, thin- to slightly thick-walled, with obtuse or acuminate apices and with brownish grey to dark grey plasmatic, membrane and encrusting pigments; elements towards the margin sparsely pigmented. **Stipe covering** a disrupted cutis with occassional ascending or erect, cylindrico-clavate terminal elements, 14-40 × 6-8 µm, thin-walled, hyaline or with pale grey plasmatic pigment. Clamp-connections very rare.

Habitat: On soil among decaying leaf litter around the base of bamboo stands, solitary or scattered.

Known Distribution: Only from the type locality.

Collections examined — Calicut District, Chelavur: 12 November 2004, AK191; 21 November 2004, AK191a; 8 October 2006, AK191b; Malappuram District, Nilambur: 11 October 2006, AK455.

A long, slender but more or less firm stipe, one to four-spored basidia, versiform cheilocystidia and a pileal covering that is basically a cutis which

becomes trichodermial at the disc, composed of cylindrical or clavate terminal elements with plasmatic, membrane and encrusting pigments are the distinguishing features of this species.

A comparison with *Lepiota roseoalba* (Hennings) Heinemann, described from East Africa by Pegler (1977), seems to be a somewhat similar species, but the present collections could be distinguished based on their reddish brown pileal squamules, non-striate margin, slender stipe and differently pigmented cylindrical terminal elements. Similarity with any other described species could not be seen as the present collections possess a unique character combination. It is considered as new to science.

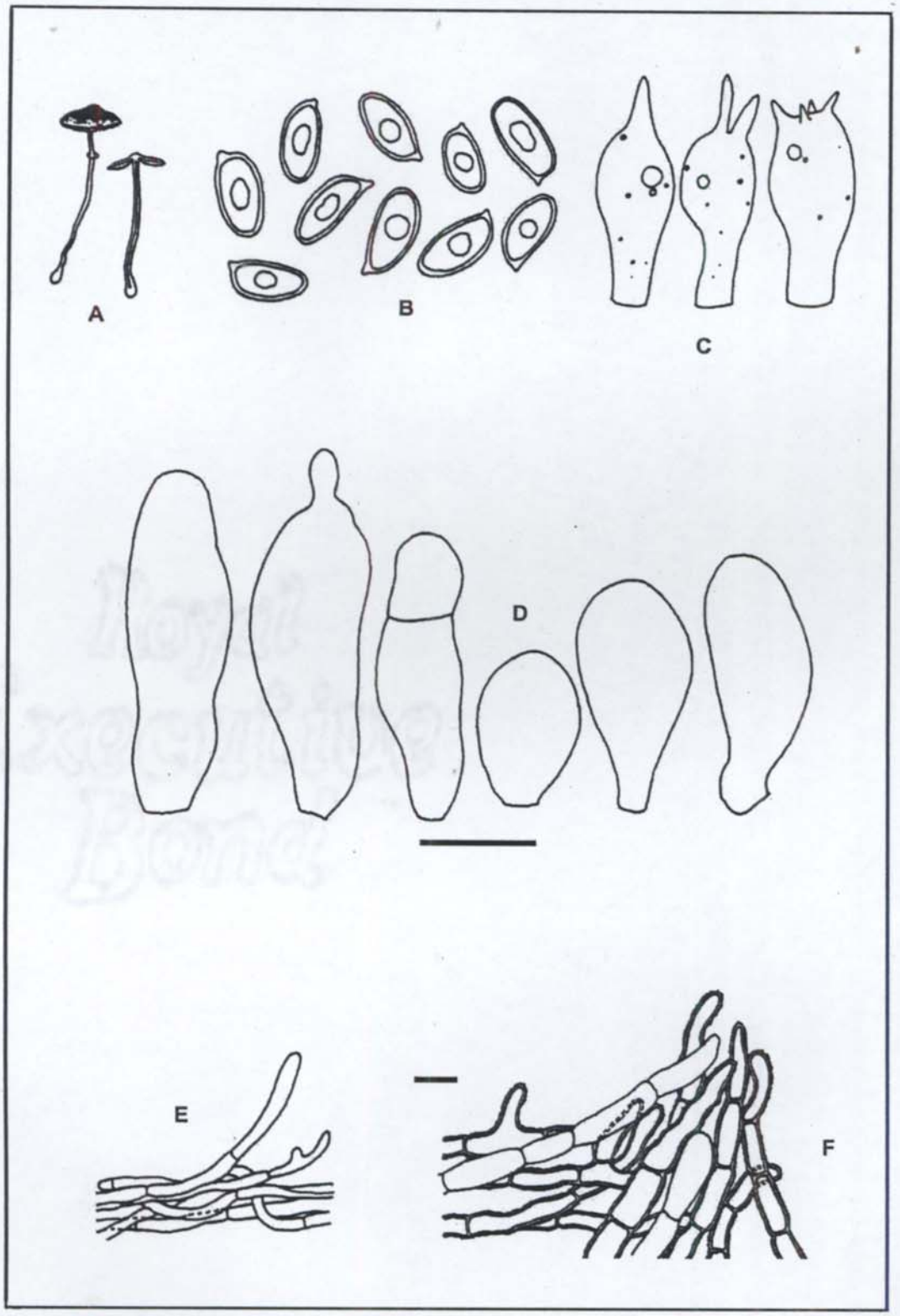


Figure 18. *Lepiota* species 4 **A.** Habit **B.** Spores **C.** Basidia **D.** Cheilocystidia **E.** Stipe covering **F.** Pileus covering. Bars = 10 µm.

***Lepiota* species 2**

Fig. 19. A-F; Pl. 18.

Basidiomata small. **Pileus** 5-24 mm diam., ovoid when very young, becoming conico-convex and finally applanate, indistinctly umbonate; surface white, furfuraceous, appressed-fibrillose or almost pruinose in some specimen especially towards the centre; non-striate; margin initially incurved, becoming straight on maturity, appendiculate, splitting up to the middle with age. **Lamellae** free, white, close to crowded, up to 3 mm wide, with lamellulae in 2-3 tiers; edge finely fimbriate under a lens, concolorous with the sides. **Stipe** 15-32 × 1.5-4 mm, central, terete, equal or rarely slightly expanded towards the base, fistulose to hollow; surface white, turning pale brownish orange (6C7) on bruising, fibrillose, with minute appressed squamules; base arising from white mycelial cords. **Annulus** superior, fibrillose, evanescent. **Context** up to 1 mm thick, white. **Odour** not distinctive. **Spore-print** white.

Spores 6-9.5 × 3.5-5 (8 ± 0.83 × 4.25 ± 0.47) µm, Q = 1.7-2.25, Qm = 1.9, oblong to subcylindrical, rarely amygdaliform, hyaline, with guttulate contents, slightly thick-walled, smooth, dextrinoid, non-metachromatic in cresyl blue, cyanophilic in cotton blue. **Basidia** 17-24 × 6.5-8.5 µm, clavate, often with guttulate contents, bearing 4 sterigmata up to 4.5 µm long. **Lamella-edge** sterile with crowded cheilocystidia. **Cheilocystidia** 14-32 × 7-13 µm, clavate to cylindrico-clavate, hyaline, thin-walled. **Pleurocystidia**

none. **Lamellar trama** subregular; hyphae inflated, septate, 2-25 µm wide, hyaline, thin-walled, inamyloid. **Subhymenium** up to 20 µm wide, cellular. **Pileal trama** parallel-interwoven; hyphae of 2-28 µm wide, highly inflated, septate, hyaline, thin-walled, inamyloid, branched. **Pileal covering** a disrupted cutis of 3-14 µm wide, thin-walled, hyaline to pale brown or pale grey filamentous hyphae with trichodermial patches of erect or ascending hyphal bundles with clavate, cylindrical or cylindrico-clavate end cells, 15-65 × 4-15 µm, with pale grey plasmatic pigments and obtusely rounded apices. **Stipe covering** a highly disrupted cutis with ascending agglutinated or loose hyphal elements with cylindrical end cells which are unpigmented, and at times branched towards the apex. All hyphae with clamp-connections.

Habitat: On soil and decaying leaf litter, solitary or scattered.

Known Distribution: Only from the type locality.

Collections examined — Malappuram District, Calicut University Campus: 4 October 2004, AK117; 5 October 2004, AK117a; 9 November 2004, AK176; 9 November 2004, AK117b; 10 November 2004, AK183; 16 November 2004, AK201.

This species is characterized by: 1) a white basidiomata; 2) colour change of stipe to pale brownish orange on bruising; 3) large mostly oblong to subcylindrical spores; 4.) cylindrico-clavate to clavate cheilocystidia 5)

cylindrical to clavate pileal elements; and 6) clamp-connections. This character combination keeps it distinct from all other previously described taxa. *Lepiota amplifolia* Murrill is a species that comes very close, but that species has 'isabelline-testaceous' scales on the pileus, 'triangular' lamellae, '7-9 cm. long' stipe that becomes rose-tinted on drying, and large spores that are '8-9 × 3.5 µm. *Leucoagaricus serenus* (Fries) Bon & Boiffard is a species that show a high degree of macroscopic similarity but microscopically it is very different.

The species is very common in the Malappuram District of Kerala, especially in the Calicut University Campus and adjoining areas.

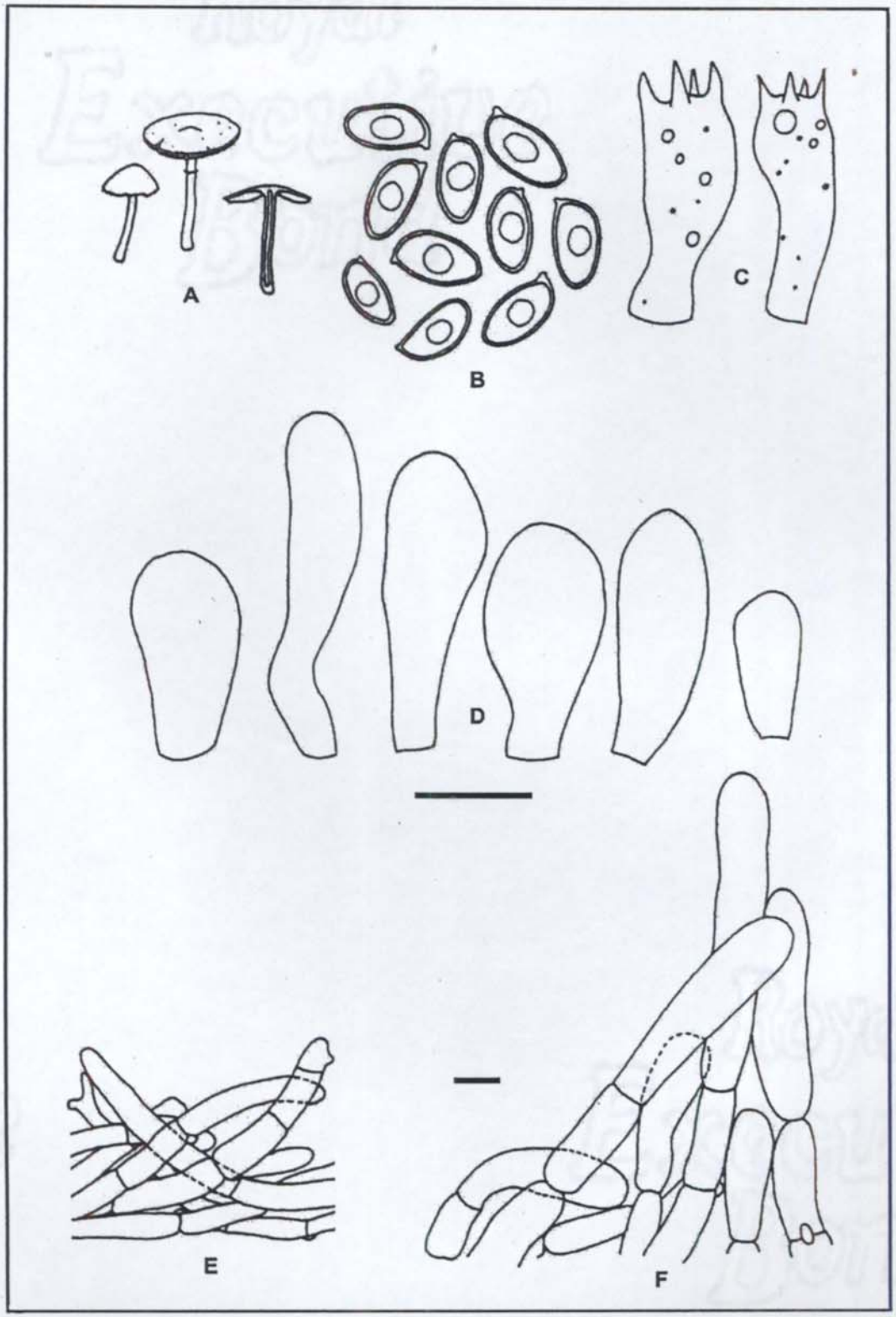


Figure 19. *Lepiota* species 2 **A.** Habit x 1 **B.** Spores **C.** Basidia **D.** Cheilocystidia **E.** Stipe covering **F.** Pileus covering. Bars = 10 µm.

Plate 17. *Lepiota* species 4 x 4

Plate 18. *Lepiota* species 2 x 4.5

5.1.1.1.5 Section ***Anomalae*** Locquin in Bulletin mensuel de la Société Linnéenne de Lyon 14: 93 (1945)

Spores ellipsoid to oblong or amygdaliform, spores dextrinoid; clamp-connections absent.

Type species: *Lepiota fuscovinacea* Møller & Lange

***Lepiota* species 7**

Fig. 20. A-F; Pl. 19.

Basidiomata small, all parts turning greyish green (27E5) on bruising. **Pileus** 20-35 mm diam., convex when young, becoming broadly convex, then applanate and finally depressed with maturity, with an indistinct umbo; surface dull white, with scattered brown (6E5-7E5) fibrillose squamules giving a granular appearance, non-striate; squamules concentrated towards the centre, appearing almost pruinose at the disc, sparse towards the margin, margin initially incurved, later straight, entire. **Lamellae** free, crowded, up to 5 mm wide, pale yellow (1A3, 2A3), with lamellulae in 8-9 tiers; edge finely fimbriate under a lens, concolorous with the sides. **Stipe** 43-72 × 2-4 mm (up to 6 mm at the base), central, terete, almost equal or expanded towards the base, slightly bulbous at the base, fistulose; surface whitish to dull white, smooth, fibrillose; base arising from a white mycelium. **Annulus** superior, membranous, evanescent. **Context** up to 5 mm thick at the disc, whitish. **Odour** not distinctive. **Spore-print** yellowish white (1A2).

Spores 5 -7 × 3-4 (6 ± 0.54 × 3.8 ± 0.44) µm, Q = 1.4-2, Qm = 1.6, ellipsoid to amygdaliform, hyaline, with refractive guttules, thick-walled (up to 1 µm), smooth, dextrinoid, non-metachromatic in cresyl blue, cyanophilic in cotton blue. **Basidia** 14-20 × 5-7 µm, cylindrico-clavate, clavate, hyaline to pale green, bearing 4 sterigmata up to 5 µm long. **Lamella-edge** sterile. **Cheilocystidia** crowded, 20-39 × 7-21 µm, mostly clavate, rarely utriform, thin- to slightly thick-walled (up to 0.5 µm), speckled with crystalline encrustations, with hyaline to greenish contents. **Pleurocystidia** absent. **Lamellar trama** subregular; hyphae 3-17 µm wide, hyaline to pale green, thin- to slightly thick-walled, inamyloid. **Subhymenium** cellular. **Pileal trama** interwoven; hyphae 4-20 µm wide, hyaline to pale grey, thin- to slightly thick-walled, inamyloid. **Pileal covering** a highly disrupted cutis towards the margin, of septate, 4-15 µm wide, thin- to slightly thick-walled hyphae with pale grey to grey plasmatic and membrane pigments, bluish green to blue pigmented at bruised parts; entirely trichodermial at the disc; terminal elements 27-65 × 10-20 µm, ellipsoid, cylindric or clavate, thin to slightly thick-walled, with pale grey to dark grey plasmatic, membrane and encrusting pigments. **Stipe covering** a cutis rarely disrupted by ascending hyphal elements; hyphae 4-16 µm wide, thin- to slightly thick-walled, hyaline to pale grey. Clamp-connections not observed.

Habitat: On soil among dead and living bamboo roots, solitary, scattered.

Known Distribution: Only from the type locality.

Collections examined — Malappuram District, Calicut University Campus: 6 June 2006, AK388; 15 June 2006, AK396, 3 July 2006, AK407; 26 September 2006, AK443; 27 September 2006, AK448.

This is an interesting species with basidiomata that turn greyish green on bruising. It is additionally characterized by pale yellow lamellae, ellipsoid to amygdaliform spores that are non-metachromatic in cresyl blue, clavate and slightly thick-walled cheilocystidia with greenish plasmatic contents and crystalline surface encrustations, elements of the pileal covering with plasmatic, membrane and encrusting pigments, and absence of clamp-connections. This character combination does not match any species description so far published.

The species is kept here under the genus *Lepiota*, as the spores clearly failed to give a metachromatic reaction with cresyl blue although the lack of clamp-connections would suggest *Leucoagaricus*. Observations during this study show that presence or absence of clamp-connections is not a reliable character to draw generic demarcations, as many collections from Kerala otherwise accepted under *Leucoagaricus* had clamp-connections and *Lepiota* species that lack clamps are also found accepted (e.g. the section *Anomalae* Locquin; the section *Fuscovinaceae* Bon & Candusso) in the literature. Following Singer's (1986) infrageneric classification, the present species may be placed inside the section *Anomalae*, a section established as a repository for all the anomalous species lacking clamp-connections. Vellinga (2003a) found this section to be a very artificial group with species

belonging to the other sections of *Lepiota* and *Leucoagaricus* as well. If the absence of clamp-connections is taken as an exception, owing to the ellipsoid to amygdaliform spore shape and the trichodermial nature of the pileal covering, the species could be placed in the section *Ovisporae*.

There are a few *Lepiota* species with a whitish context, that show a greenish colour change on handling or when bruised. *Lepiota viriditincta* (Berkeley & Broome) Saccardo is one such species belonging to the section *Ovisporae* that has been reported from Sri Lanka (Pegler 1972, 1986) and Kerala, India (Manimohan *et al.* 1988). But that species has smaller basidiomata, less dense pileal squamules, larger spores, smaller cheilocystidia, and clamp-connections. *Lepiota cyanescens* Beeli also differs in being larger-sized and with much larger spores. *Lepiota caerulescens* Peck another white fleshed species is known to show a combination of blue, green and reddish tints upon handling (Akers et al. 2000). The other species that turn green or bluish green on bruising, like *Lepiota viridiflava* Petch, *Leucoagaricus viridiflavoides* Akers & Angels and *Leucocoprinus sulphurellus* Pegler all have a noticeably yellow context apart from other differences.

148-A

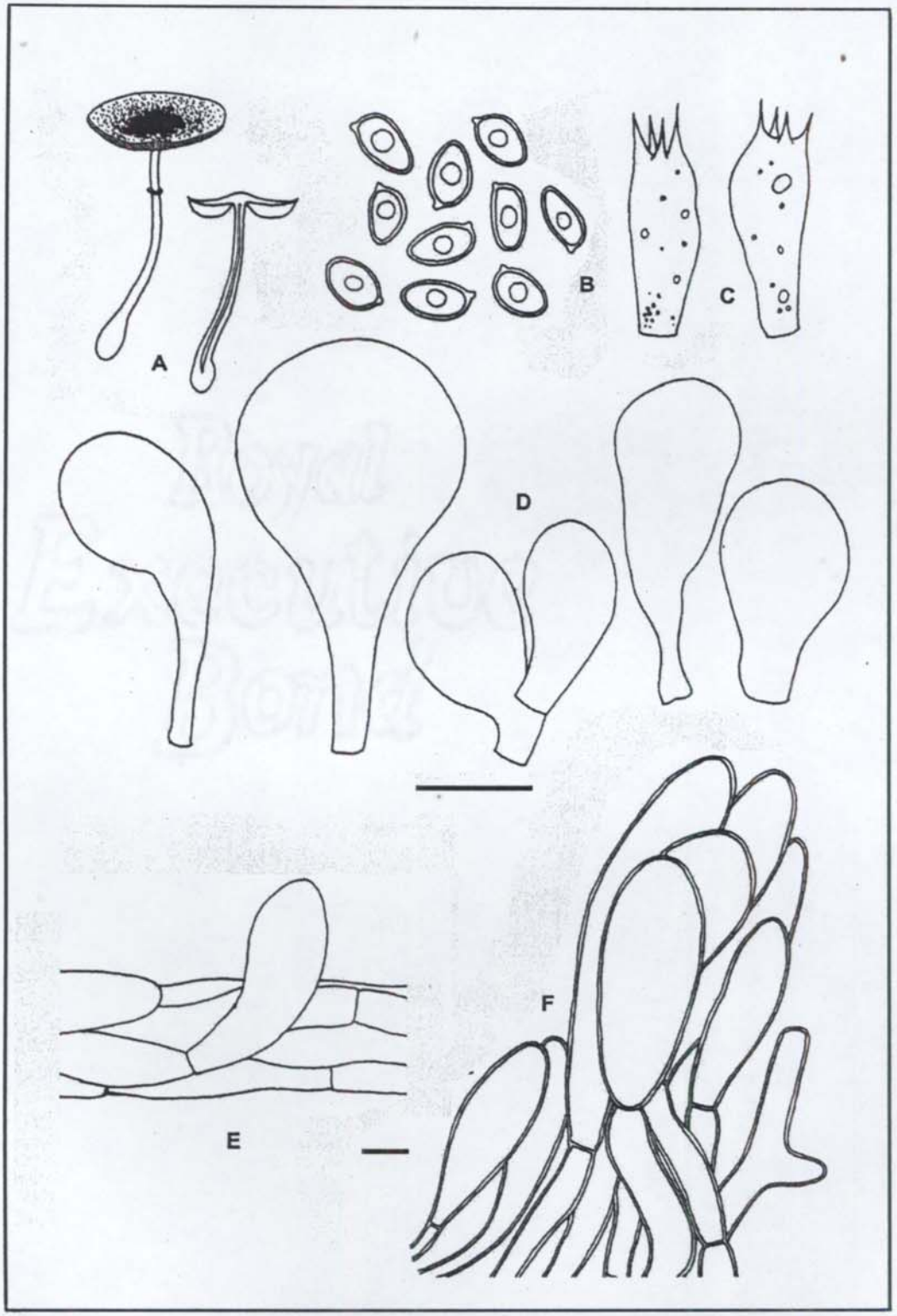


Figure 20. *Lepiota* species 7 **A.** Habit x 1 **B.** Spores **C.** Basidia **D.** Cheilocystidia **E.** Stipe covering **F.** Pileus covering. Bars = 10 µm.

Lepiota plumbicolor (Berkeley & Broome) Saccardo in Sylloge Fungorum 5: 63 (1887)

Agaricus plumbicolor Berkeley & Broome in Journal of Linnean Society, Botany 11: 510 (1871)

Fig. 21. A-F; Pl. 20.

Basidiomata small. **Pileus** 17-25 mm diam., initially conico-convex, becoming broadly convex to applanate with an obtuse umbo; surface white with brownish grey (8F1, 8F2) appressed squamules which are concentrated towards the disc, cracking to reveal the under lying white context at the disc at maturity, finely radially striate towards margin; margin initially incurved, becoming straight to upturned, initially entire, becoming fissile with age. **Lamellae** free, white, crowded, thin, up to 3 mm wide, ventricose, with lamellulae in 2-3 tiers; edge finely fimbriate under a lens, concolorous with the sides. **Stipe** 22-35 × 2-4 mm, central, terete, almost equal, expanding towards the base, hollow; surface whitish above and dark brown (8F6, 8F7) below the annulus, fibrillose, with comparatively more fibrils towards the base; base with white mycelial cords. **Annulus** central to superior, fugacious. **Context** up to 2 mm thick at the disc, thinner towards margin, whitish, changing brownish grey (7D2, 8D2) on exposure. **Odour** not distinctive. **Spore-print** not obtained.

Spores 5-8 × 3.5-5 (6.7 ± 0.5 × 4 ± 0.43) µm, Q = 1.4-2.1, Qm = 1.66, ellipsoid to oblong-ellipsoid, with refractive guttules, thick-walled, smooth, dextrinoid, non-metachromatic in cresyl blue, cyanophilic in cotton blue.

Basidia 12-16 × 7-8.5 µm, clavate, with guttulate contents, 4-spored; sterigmata less than 3 µm in length. **Lamella-edge** sterile. **Cheilocystidia** 11-34 × 7-14 µm, abundant, disintegrating in old dried specimens, clavate, inflated-clavate, obovoid, or utriform, thin-walled, hyaline. **Pleurocystidia** absent. **Lamellar trama** subregular, of thin-walled, septate, hyaline, inamyloid hyphae, 2-7 µm wide and inflated up to 30 µm. **Subhymenium** cellular. **Pileal trama** interwoven, made of 6-32 µm wide, highly inflated, hyaline to pale yellow, thin-walled, inamyloid hyphae with obtuse tips. **Pileal covering** a disrupted cutis of 3-15 µm wide, pale brown to brown, thin-walled filamentous hyphae, with trichodermial patches of erect hyphal bundles terminated by cylindrical end-cells, entirely trichodermial towards the centre; terminal elements 15-162 × 4-15 µm, cylindrical, thin-walled, with thick dark brownish grey plasmatic pigments and obtuse rounded apices. **Stipe covering** a highly disrupted cutis of loose filamentous hyphae with cylindrical, 13-87 × 4-7 µm large, thin-walled elements with pale brown to brown pigments, entirely trichodermial towards base. All hyphae lack clamp-connections.

Habitat: On decaying leaf litter and wood chips on ground, scattered in groups.

Known Distribution: Brazil, Sri Lanka

Collections examined — Wayanad District, Kottathara: 1 October 2004, AK109; Calicut District, Mananchira: 2 October 2004, AK114; 5 October 2004, AK114a.

The species is characterized by: 1) a pileus up to 2.5 mm in diameter, covered with brownish grey or blackish appressed squamules; 2) ellipsoid to oblong-ellipsoid spores more than 5 µm long and less than 5 µm broad; 3) pileal surface with disrupted trichodermial patches comprised of brownish grey plasmatically pigmented cylindrical terminal elements; 4) stipe covering with similar structure and terminal elements as of the pileal surface; and 5) the total absence of clamp-connections. The species was placed by Pegler (1972, 1986) under the section *Anomalae* Locquin mainly because of the absence of clamp-connections.

The collections from Kerala have characters agreeing with the account of the species given by Pegler (1972, 1986), based on the type material (Thwaites 864 cum icon, December 1868, deposited at K) originally described by Berkeley & Broome from Sri Lanka. The Kerala collections, however, have whitish lamellae, fugacious annulus, and much wider cheilocystidia. This forms the first record of the species from India.

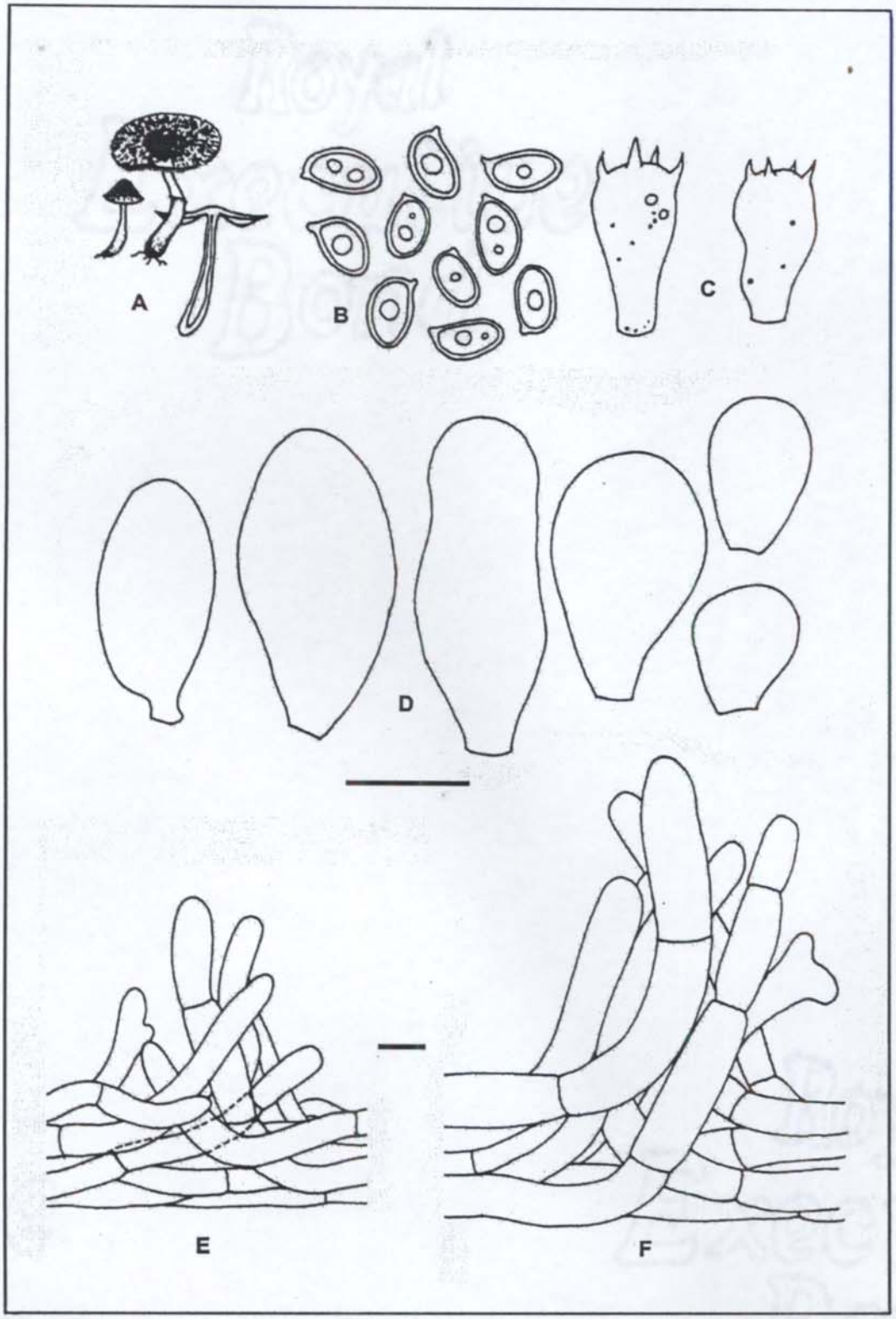


Figure21. *Lepiota plumbicolor* **A.** Habit x 1 **B.** Spores **C.** Basidia **D.** Cheilocystidia **E.** Stipe covering **F.** Pileus covering. Bars = 10 µm.

Plate 19. *Lepiota* species 7 x 3

Plate 20. *Lepiota plumbicolor* x 3.5

Lepiota murino-capitata Dennis in Kew Bulletin 15: 114 (1961)

Fig. 22. A-F; Pl. 21.

Basidioma very small. **Pileus** 9 mm diam., initially broadly convex, applanate at maturity with an indistinct umbo; surface entirely covered with dark grey (1F1), minute, appressed squamules that are denser towards the disc; margin incurved when young, becoming straight on maturity, eroded. **Lamellae** free, initially white, turning pale yellow (2A3), crowded, thin, less than 1 mm wide, with lamellulae of two lengths; edge finely fimbriate under a lens, concolorous with the sides. **Stipe** 27 × 1 mm, central, terete, equal, solid; surface dull white to grey (1F1), turning brown (6E6) on bruising, fibrillose; base arising from white mycelial cords. **Annulus** superior, fibrillose, fixed, persistant. **Context** less than 1 mm thick, dull white. **Odour** not distinctive. **Spore-print** not obtained.

Spores 4.5-6 × 3.5-4.5 (5.35 ± 0.5 × 3.98 ± 0.9) µm, Q = 1.2-1.5, Qm = 1.27, subamygdaliform in side view, ovoid in frontal view, hyaline, with oil guttules, thick-walled, smooth, dextrinoid, non-metachromatic in cresyl blue, cyanophilic in cotton blue. **Basidia** 14.5-21 × 7.5-11 µm, clavate to broadly clavate, with guttulate contents, tetrasporic, sterigmata up to 3 µm long. **Lamella-edge** sterile. **Cheilocystidia** abundant, 11-24 × 7-13.5 µm, clavate to obovoid, thin-walled, hyaline. **Pleurocystidia** absent. **Lamellar trama** subregular, of thin-walled, inflated, septate, hyaline to pale brown and 5-15 µm wide hypae, inamyloid. **Subhymenium** cellular. **Pileal trama** highly and

irregularly interwoven, composed of 5-25 µm wide, inflated, septate, hyaline to pale yellow, thin-walled, inamyloid, hyphae. **Pileal covering** a disrupted cutis of filamentous hyphae with loosely arranged, ascending or erect terminal elements; terminal elements 15-42 × 5-8.5 µm, cylindrical, strangulated, thin- to slightly thick-walled, with brown to dark greyish brown, plasmatic and membrane pigments. **Stipe covering** a cutis with ascending, cylindrical terminal elements 15-35 × 3-6 µm, thin-walled, with a pale grey plasmatic pigment. All hypahe lack clamp-connections.

Habitat: On decaying leaf litter, solitary.

Known Distribution: Venezuela.

Collection examined — Malappuram District, Calicut University Campus: 26 October 2004, AK152.

This species is distinguished by its dark grey pileus with appressed squamules, white lamellae turning pale yellow, subamygdaliform spores that are non-metachromatic in cresyl blue, fixed annulus, and cuticular pileal covering with loosely arranged hyphae terminated by darkly pigmented cylindrical elements. Clamp-connections are absent in this species.

Lepiota murino-capitata was originally described and reported from Venezuela by Dennis (1961, 1970), with characters similar to those shown by the collection from Kerala. However in the Kerala collection, the lamellae

were observed to be initially white that gradually became pale yellow, the stipe showed a dull white to grey colour that turned brown on bruising, the fibrillose annulus was persistent and was without a grey-coloured edge. Despite of these small differences, the present collection is considered here as that species.

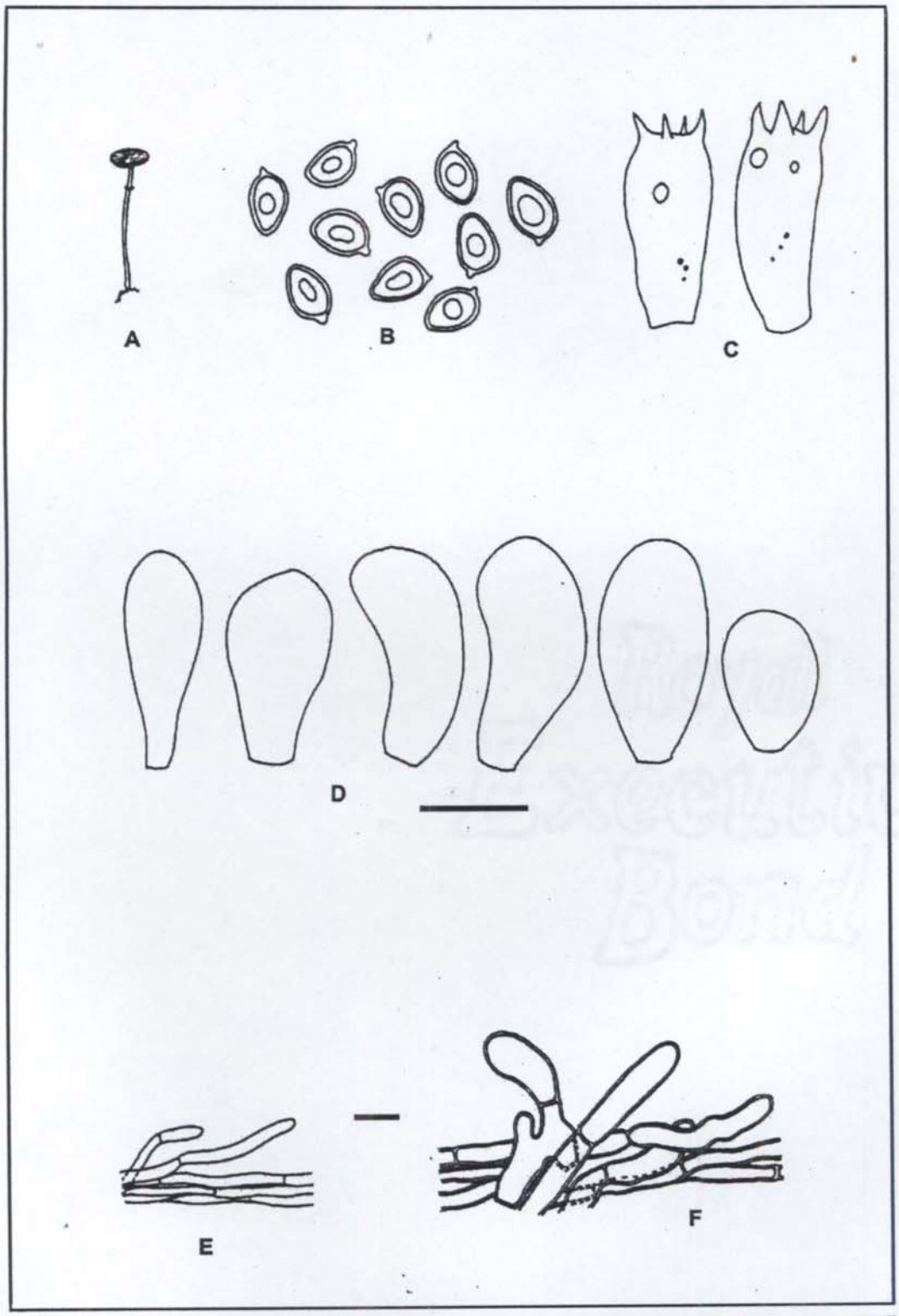


Figure 22. *Lepiota murino-capitata* **A.** Habit x 1 **B.** Spores **C.** Basidia **D.** Cheilocystidia **E.** Stipe covering **F.** Pileus covering. Bars = 10 µm.

5.1.2 *Cystolepiota* Singer

Cystolepiota Singer in Singer & Digilio in Lilloa 25: 281 ('1951') (1952)

Pulverolepiota Bon in Documents Mycologiques 22: 30 (1993)

Lepiota subgenus *Sphaerocystae* Wasser in Ukrayins'kyi botanichnyi zhurnal 35: 517 (1978)

Basidiomata somewhat small; pileus densely covered with granular to floccose or pyramidal squamules; lamellae free; stipe central, almost equal, covered with squamules similar to those on the pileal surface; annulus zonate; spore-print whitish to yellowish white; spores small, smooth, lacking germ pore, inamyloid, hyaline, thin- to slightly thick-walled; cystidia present, rarely absent; hymenophoral trama subregular; pileus covering made of loosely arranged inflated ellipsoid or globose elements; clamp-connections present, rarely absent.

Type species: *Cystolepiota constricta* Singer

5.1.2.1 KEY TO THE *CYSTOLEPIOTA* SPECIES OF KERALA

1. Hymenial cystidia and clamp-connections present **2**
1. Cystidia absent; clamp-connections absent; spores 4-6 × 2-3 µm..... ..... ***Cystolepiota pulverulenta***
2. Cheilocystidia and pleurocystidia with yellowish contents and exudates; pileal covering made of subglobose to globose elements; spores 4-5 × 2-3 µm ..... ***Cystolepiota cystidiosa***
2. Cheilocystidia without any contents or exudates; pleurocystidia absent; pileal covering made of inflated cylindrical or ellipsoid cells; spores 4-6 × 2.5-3.5 µm ..... ***Cystolepiota* species 1**

Cystolepiota pulverulenta (Huijsman) Vellinga in Persoonia 14: 407 (1992)

Lepiota pulverulenta Huijsman in Persoonia 1: 328 (1960)

Leucoagaricus pulverulentus (Huijsman) Bon in Documents Mycologiques 8:70 (1978)

Leucoagaricus pulverulentus (Huijsman) Moser in Röhrlinge Blätterpilze 4: 246 (1978)

Pulverolepiota pulverulenta (Huijsman) Bon in Documents Mycologiques 22: 30 (1993)

Leucoagaricus pulverulentus form *minimus* Bon *et al.* in Documents Mycologiques 19: 54 (1989)

Pulverolepiota pulverulentus form *minimus* Bon *et al.* in Documents Mycologiques 22: 30 (1993)

Cystolepiota pulverulenta form *minima* (Bon *et al.*) Chiusa in Revista di Mycologia 41: 152 (1998)

Fig. 23. A-E; Pl. 22.

Basidiomata small. **Pileus** 7-8 mm diam., subglobose when young, becoming broadly convex and finally applanate with an indistinct obtuse umbo; surface whitish with pale brown tinges towards the disc, granular to downy-wooly or floccose; margin incurved, becoming straight, appendiculate. **Lamellae** free, white, moderately crowded, less than 2 mm wide, with lamellulae in 2-3 tiers; edge finely fimbriate under a lens, concolorous with the sides. **Stipe** 15-32 × 1-2 mm, central, terete, almost equal, solid; surface whitish, fibrillose to granulose. **Annulus** not observed. **Context** less than 1 mm thick, white. **Odour** not distinctive. **Spore-print** not obtained.

Spores 4-6 × 2-3 (4.85 ± 0.52 × 2.7 ± 0.3) µm, Q = 1.5-2, Qm = 1.66, subcylindric to cylindric, hyaline, with refractive guttules, thin-walled, smooth, inamyloid, metachromatic in cresyl blue, cyanophilic in cotton blue. **Basidia** 10-20 × 6-7 µm, clavate, with guttulate contents, bearing 4 sterigmata up to 3 µm long. **Lamella-edge** fertile. **Cheilocystidia** absent. **Pleurocystidia** absent. **Lamellar trama** subregular; hyphae 3-17 µm wide, inflated, hyaline, thin-walled, septate, inamyloid. **Subhymenium** cellular. **Pileal trama** interwoven; hyphae 5-18 µm wide, inflated, hyaline to pale brown, thin-walled, inamyloid. **Pileal covering** a trichodermium formed of irregular chains of inflated, ellipsoid, fusoid or cylindrical elements, 10-59 × 4-15 µm, arising from repent, 2-13 µm wide, thin-walled filamentous hyphae. **Stipe covering** a disrupted cutis of loose filamentous hyphae with cylindrical 15-66 × 4-10 µm terminal elements, at times apically branched. All hypahe lack clamp-connections.

Habitat: On soil and among decaying leaf litter, solitary or scattered in groups.

Known Distribution: ASIA, EUROPE, USA, Venezuela.

Collections examined — Malappuram District, Calicut University Campus: 9 November 2004, AK182; 26 September 2006, AK444; 27 September 2006, AK444a; 29 September 2006, AK450.

This species is distinct with a wooly-floccose pileal surface, cylindric, inamyloid spores that are metachromatic in cresyl blue, lack of cystidia, a pileal covering of inflated or cylindrical elements and hyphae devoid of clamp-connections. The present collections perfectly agree with the descriptions of the species by Huijsman (1960), Vellinga (1992), Migliozzi *et al.* (1989b), Bon (1996) and Vellinga (2001f). All the European collections, however, had a slightly rough spore wall. This is the first report of the species from India.

The metachromatic reaction of the spores in cresyl blue, the shape of pileal elements and the absence of clamp-connections indicate a placement inside the genus *Leucoagaricus*, but Vellinga (1992) justified its position inside *Cystolepiota*. The arguments that she raised in favour of such a placement are: 1) The floccose type of pileal and stipe covering are not found in *Leucoagaricus* taxa. 2) The spore size and shape resemble more of those of *Cystolepiota* members'. 3) Many *Cystolepiota* species exhibit similar metachromatic reactions with cresyl blue. 4) Spores of this species are weakly dextrinoid. 5) The species of *Leucoagaricus* have conspicuous cheilocystidia 6) The species of *Leucoagaricus* have a totally different kind of pileal covering made of repent or ascending to erect, articulate hyphae and 7) A few *Cystolepiota* species are exceptionally found without clamp-connections. In view of all these arguments and on the basis of molecular evidences (Vellinga 2003a, 2004a) indicating its phylogeny, this species is placed here under the genus *Cystolepiota*.

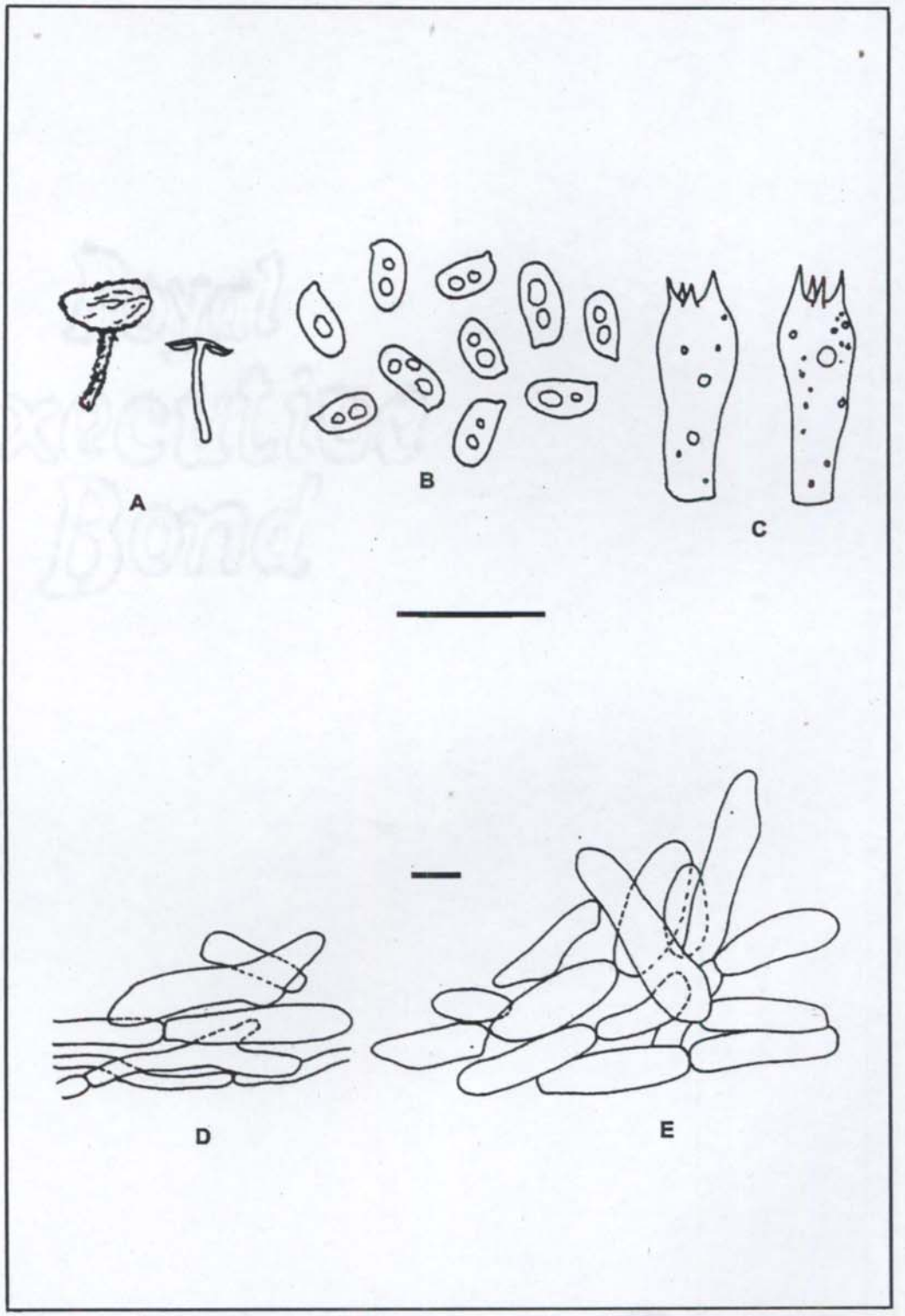


Figure 23. *Cystolepiota pulverulenta* **A.** Habit x 1 **B.** Spores **C.** Basidia **D.** stipe covering **E.** Pileus covering. Bars = 10 µm.

Plate 21. *Lepiota murino-capitata* x 5

Plate 22. *Cystolepiota pulverulenta* x 4.5

Cystolepiota cystidiosa (Smith) Bon in Documents Mycologiques. 11 (43): 26 (1981)

Lepiota cystidiosa Smith in Papers from the Michigan Academy of Science, Arts and Letters 27: 58 ('1941') (1942)

Lepiota luteicystidiata Reid in Fungorum rariorum icons coloratae 2: 9 (1967)

Cystolepiota luteicystidiata (Reid) Bon in Documents Mycologiques 6 (24): 43 (1976)

Lepiota lycoperdoides Kreisel in Wissenschaftliche Zeitschrift der Ernst Moritz Arndt-Universität Greifswald 16: 238 (1967)

Cystolepiota luteicystidiata var. *lycoperdoides* (Kreisel) Bon in Documents Mycologiques 11 (43): 26 (1981)

Fig. 24. A-G; Pl. 23.

Basidiomata small. **Pileus** 7-22 mm diam., globose to subglobose when young, becoming broadly convex to applanate at maturity, with an indistinct umbo; surface yellowish white (2A2, 3A2), densely covered with detersile, granular to floccose, greyish orange (5B3) to light brown (6D7) or brown (7E5) squamules; squamules erect and conical towards the centre, paler and sparsely distributed towards margin; margin initially incurved, becoming straight, appendiculate. **Lamellae** free, yellowish white (3A2) to pastel yellow (3A4) turning dark brown (6E8) on bruising or on drying, moderately crowded to crowded, up to 4 mm wide, with lamellulae in 3-4 tiers; edge finely fimbriate under a lens, concolorous with the sides. **Stipe** 25-43 x 1-3 mm, central, terete, almost equal or slightly tapering towards apex, fistulose; surface yellowish white (2A2), turning brown (7E5) to dark brown (6E8) on bruising, covered with greyish orange (5B3) to light brown

(6D7), floccose scales below the annulus that are easily removed on handling; base arising from a white mycelium. **Annulus** present as a thin fibrillose ring, superior, ascending, evanescent. **Context** up to 2 mm thick, whitish. **Odour** not distinctive. **Spore-print** yellowish white (1A2).

Spores 4-5 x 2-3 (4 ± 0.31 × 2.3 ± 0.44) µm, Q = 1.3-2.25, Qm = 1.9, ellipsoid to subcylindric, hyaline, with oil guttules, smooth, thin- to slightly thick-walled, inamyloid, non-metachromatic in cresyl blue, cyanophilic in cotton blue. **Basidia** 12-20 x 5-7 µm, cylindrico-clavate, sometimes slightly flexuose, with minute guttulate contents and yellowish exudates, bearing 4 sterigmata up to 4 µm long. **Lamella-edge** fertile. **Cheilocystidia** abundant, 20-45 x 6-15 µm, versiform: fusiform, clavate, ventricose-rostrate, obovoid, or utriform; many with subcapitate or slightly protruding apices, hyaline to pale yellow, thin- to slightly thick-walled (up to 0.5 µm), sometimes with yellowish exudates on the surface, strongly dextrinoid. **Pleurocystidia** 35-53 x 8-18 µm, abundant, evenly dispersed on the sides of lamellae, fusiform, broadly fusiform, ventricose-rostrate, or obclavate, hyaline to pale yellow, thin-walled, dextrinoid, with yellowish exudates on the surface. **Lamellar trama** regular to subregular, broad (up to 115 µm); hyphae thin- to slightly thick-walled, hyaline, 2-23 µm wide, inflated, inamyloid. **Subhymenium** cellular. **Pileal trama** interwoven hyphae inflated, 3-25 µm wide, hyaline to pale yellowish, slightly thick- to thick-walled (up to 1 µm), inamyloid. **Pileal covering** composed of subglobose to globose cells (sphaerocysts), 17-80 µm in diameter, interspersed with 2-7 µm wide, thin- to slightly thick-walled

hyphae with pale yellowish to light brown plasmatic and membrane pigments. **Stipe covering** a loosely arranged cutis of 2-7 µm wide, slightly thick- to thick-walled (up to 1 µm), pale yellowish to pale brownish hyphae and covered with globose, subglobose or ellipsoid elements. Clamp-connections present, especially abundant on pileal hyphae.

Habitat: On soil, among decaying leaf litter, solitary or gregarious.

Known Distribution: USA, EUROPE.

Collections examined — Thiruvananthapuram District, Palode: 2 August 2006, AK421; 3 August 2006, AK421a; 4 August 2006, AK435; Kallar: 4 August 2006, AK428.

Characters of the examined specimens agree very well with those of *Cystolepiota cystidiosa* from the Netherlands described by Vellinga & Huijser (1998) and Vellinga (2001e). The Kerala collections, however, lack the pinkish tinge on fruit bodies during colour change with maturity and on bruising. A closely related species, *C. hetieri* differs by the absence of yellowish contents in its cystidia. *C. cystidiosa* has never been reported before from Asia.

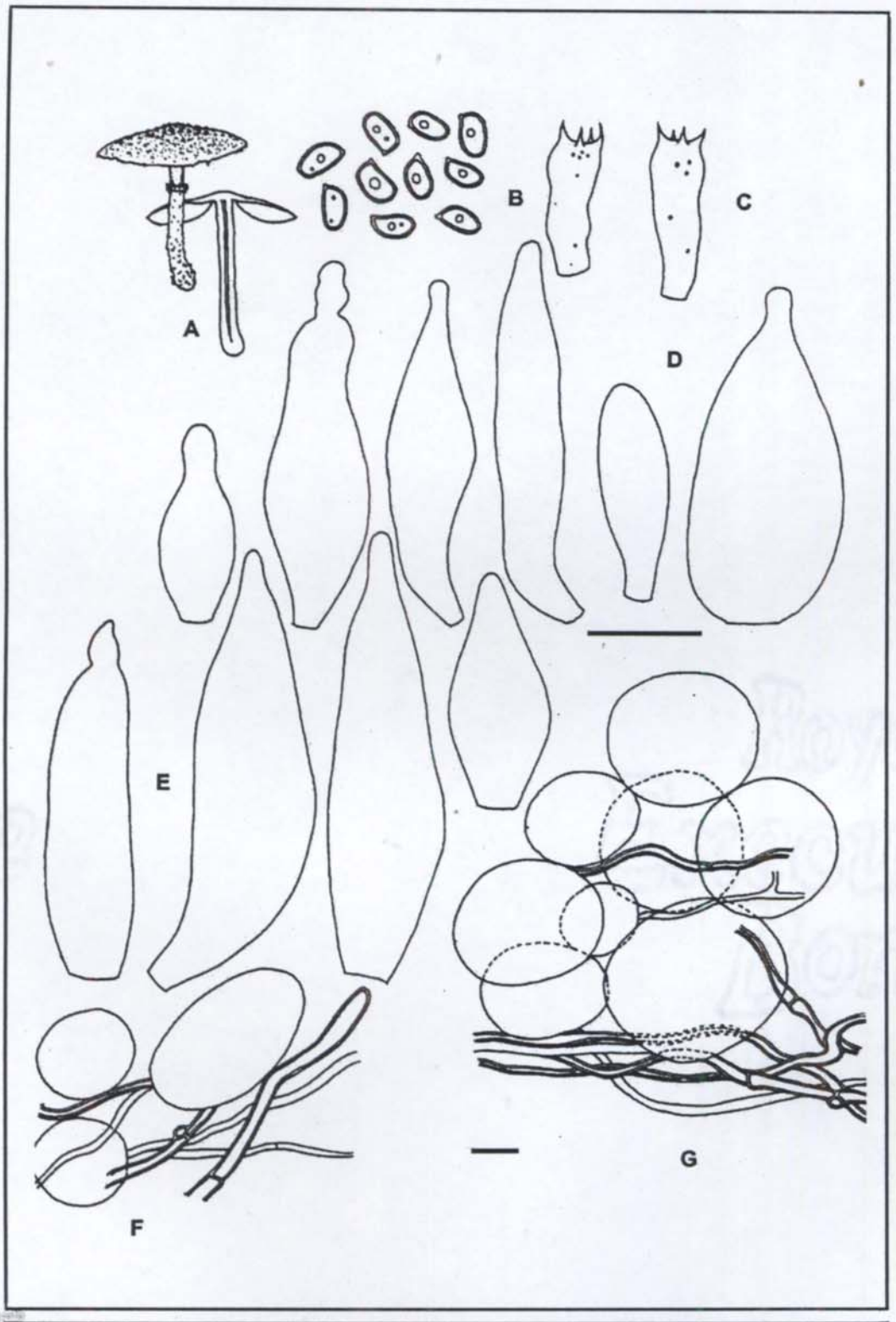


Figure 24. *Cystolepiota cystidiosa* **A.** Habit x 1 **B.** Spores **C.** Basidia **D.** Cheilosystidia **E.** Pleurocystidia **F.** Stipe covering **G.** Pileus covering. Bars = 10 µm.

***Cystolepiota* species 1**

Fig. 25. A-F; Pl. 24.

Basidiomata small. **Pileus** 17.5-20 mm diam., globose when very young, expanding to convex and finally applanate on maturity; surface whitish, with yellowish white (4A2) to pale yellowish (4A3) furfuraceous squamules that are almost spiny towards the centre, non-striate; margin initially incurved, becoming straight, entire. **Lamellae** free, whitish, moderately crowded, up to 2 mm wide, with lamellulae in 3-4 tiers; edge finely fimbriate under a lens, concolorous with the sides. **Stipe** 20-23 × 1-1.5 mm, central, terete, almost equal, with a subbulbous base, solid; surface whitish turning brownish orange (7C4) on bruising, with detersile, cottony squamules; base arising from white mycelial cords. **Annulus** not observed. **Context** up to 1 mm thick, whitish, turning brownish orange (7C4) on exposure. **Odour** not distinctive. **Spore-print** not obtained.

Spores 4-6 × 2.5-3.5 (5 ± 0.44 × 3 ± 0.22) µm, Q = 1.3-2, Qm = 1.7, ellipsoid, hyaline, with refractive guttules, slightly thick-walled, smooth, inamyloid, non-metachromatic in cresyl blue, cyanophilic in cotton blue. **Basidia** 13-22 × 6-8 µm, clavate, with guttulate contents, hyaline, 4-spored, with sterigmata up to 3 µm long. **Lamella-edge** sterile. **Cheilocystidia** crowded, 15-55 × 5-17 µm, cylindrico-clavate, clavate, utriform, thin-walled, hyaline, guttulate, with basal clamp-connections. **Pleurocystidia** absent. **Lamellar trama** subregular; hyphae 2-17 µm wide, slightly inflated, hyaline,

thin-walled, inamyloid. **Subhymenium** cellular. **Pileal trama** interwoven; composed of inflated, septate, 3-17 µm wide, hyaline, thin-walled, inamyloid hyphae. **Pileal covering** a highly disrupted cutis composed of both ascending or erect, inflated, 2-15 µm wide hyphae and loosely arranged detersile chains of cylindrical or ellipsoid large 17-42 × 4-13 µm, elements; hyphae thin-walled and with pale yellowish to brown plasmatic pigments. **Stipe covering** a disrupted cutis of loosely arranged cylindrical or ellipsoid elements similar to those of the pileal covering. All hyphae with clamp-connections.

Habitat: On soil among decaying leaf litter, solitary.

Known Distribution: Only from the type locality.

Collections examined — Thiruvananthapuram District, Palode: 18 July 2005, AK355; 20 July 2005, AK370.

The outstanding characters of this small-sized species are the furfuraceous yellowish squamules that become somewhat spiny towards the centre, ellipsoid spores that are inamyloid and non-metachromatic in cresyl blue, cylindrico-clavate, clavate or utriform cheilocystidia and a pileal covering with loosely attached chains of cylindrical or ellipsoid elements. This character combination of this species indicates that it may be placed either in the genus *Cystolepiota* or in *Lepiota* section *Echinatae*. The

inamyloid spores and a pileal covering with detersile inflated elements point to an affinity with *Cystolepiota*, although species with these characters are also found accepted under *Lepiota*. *Lepiota boertmanni* Knudsen is an example of a very similar, but exceptional species in *Lepiota* having medium-sized spores that are inamyloid. However, the pileal and stipe coverings of the present species with detersile elements that do not agglutinate in to conical squamules are more similar to those of species of *Cystolepiota*. Hence the present species may be better placed in *Cystolepiota* till further information supportive of its correct generic placement becomes available. A similar character combination is not seen in any of the known species of both *Lepiota* and *Cystolepiota*. Hence this species is presently considered as hitherto undescribed. A closely related species, *L. boertmannii* mainly differs in having pointed and rather persistant dark brown scales and an epicutis with three cell types; the apical ones being subglobose or ovoid. *Lepiota pseudogranulosa* (Berkeley & Broome) Saccardo (= *C. pseudogranulosa* (Berkeley & Broome) Pegler) is 'vinaceous-buff' coloured at the pileal disc, possess smaller and dextrinoid spores, cylindrical cheilocystidia and lack pale yellowish to brown plasmatic pigments in their pileal elements. Another species with similar spore-size and shape and a comparable pileal structure is *C. pulverulenta* (Huijsman) Vellinga (= *Leucoagaricus pulverulentus* (Huijsman) Bon) that could be easily differentiated based on its dextrinoid spores and the absence of cystidia.

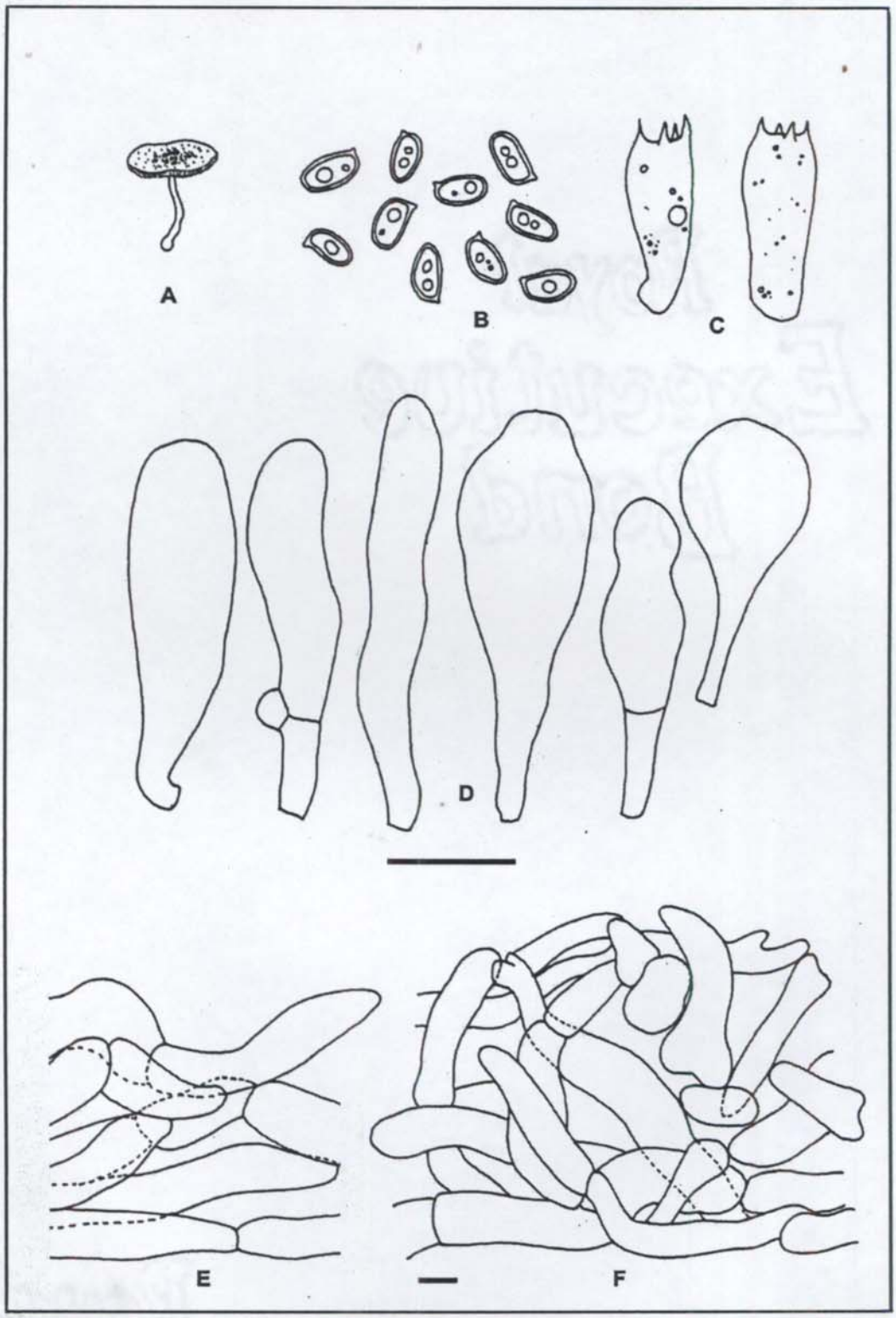


Figure25. *Cystolepiota* species 1 **A.** Habit x 1 **B.** Spores **C.** Basidia **D.** Cheilocystidia **E.** Stipe covering **F.** Pileus covering. Bars = 10 µm.

Plate 23. *Cystolepiota cystidiosa* x 3.5

Plate 24. *Cystolepiota* species 1 x 5

5.1.3 ***Leucocoprinus*** Patouillard

Leucocoprinus Patouillard in Journal de Botanique, Paris 2: 16 (1888)

- *Mastocephalus* Battara ex Kuntze in Revisio generum plantarum 2: 857 (1891)

- *Lepiota* subgenus *Leucobolbitius* Lange in Flora agaricina Danica 1: 23 (1935) not valid

- *Lepiota* section *Striatae* Murrill in North American Flora 10: 42 (1914)

Basidiomata small to large, in a few species exhibiting greenish colour change on exposure to ammonia; pileal margin striate; lamellae free, thin; lamella-edge in some species with dark grey spots; stipe central, almost equal, with a slight expansion towards the base, smooth, fibrillose or with distinct squamules; annulus mostly membranous, rarely fibrillose, usually movable; context in many species changing colour on exposure, bruising or with age; spore-print pure white to yellowish; spores small to large, cylindrical, ovoid, ellipsoid, or amygdaliform, dextrinoid, metachromatic in cresyl blue, germ-pore present or absent, smooth, hyaline, slightly thick- to thick-walled; pseudoparaphyses in hymenium abundant and well-developed; cheilocystidia present, rarely absent; pleurocystidia not present in most species; lamellar trama regular to subregular, of inflated hyphae; pileal covering variable; stipe covering almost similar to that of the pileus; clamp-connections very rare or almost absent

Type species: *Lepiota cepaestipes* (Sowerby) Kummer (= *Leucocoprinus cepaestipes* (Sowerby) Patouillard)

5.1.3.1 KEY TO THE *LEUCOCOPRINUS* SPECIES OF KERALA

1. Spores with a conspicuous germ-pore..... **2**
1. Spores without a germ-pore or if present rudimentary..... **13**
2. Basidiomata turning greenish on reaction with ammonia..... **3**
2. Basidiomata not turning greenish on reaction with ammonia..... **4**
3. Annulus fixed and with dense reddish brown squamules at the rim; cheilocystidia lageniform, utriform or broadly clavate with apical prolongation; pileal covering made of lageniform terminal elements with apical prolongation; spores 7-13 × 5-8 µm ..... ***Leucocoprinus holospilotus***
3. Annulus evanescent, without any coloured squamules at the rim; cheilocystidia narrowly cylindric to flexuose without apical prolongation; pileal covering made of narrowly cylindrical to somewhat flexuose terminal elements; spores 5-13 × 4.5-11 µm ..... ***Leucocoprinus lacrymans***
4. Pileal covering with inflated globose to subglobose elements **5**
4. Pileal covering without inflated to globose elements..... **9**
5. Basidiomata extremely fragile, pastel yellow; spores 9.5-15 × 7-11µm, often constricted apically into a short cylindrical region ..... ***Leucocoprinus fragilissimus***
5. Basidiomata more or less sturdy, whitish, dull white, orange grey or yellowish white; spores relatively smaller and without apical constriction **6**
6. Lamellae initially white, later turning yellowish white, yellowish brown or orange grey; stipe exhibiting colour change on bruising..... **7**
6. Lamellae white to yellowish white; stipe without colour change on bruising..... **8**
7. Basidiomata somewhat fragile; annulus inferior to almost central, with concolorous squamules; cheilocystidia inflated clavate to ovoid; spores 8-11 × 5.5-7 µm ..... ***Leucocoprinus ianthinus***

7. Basidiomata sturdy; annulus superior, with dark brown squamules on the upper side; cheilocystidia lageniform or utriform with apical appendages; spores 8-11 × 6-8 µm..... ***Leucocoprinus* species 1**
8. Pileus yellowish white with brown squamules; spores 9-13 × 6-9 µm..... ***Leucocoprinus brebissoni***
8. Pileus white to pinkish white with cinnamon, rust brown or reddish brown squamules; spores 6-10 × 4.5-6.5 µm ..... ***Leucocoprinus venezuelanus***
9. Pileus whitish with dark brown, grey or dark grey squamules..... **10**
9. Pileus white or yellow with almost concolorous squamules **12**
10. Basidiomata somewhat fragile; stipe slender (1-2 mm wide); context colour remaining unchanged; spores 9-12 × 6-7 µm ..... ***Leucocoprinus* species 2**
10. Basidiomata not fragile; stipe rather robust; context whitish turning brown on exposure **11**
11. Pileus less than 20 mm diameter; spores 7-10 × 5-6 µm, ovoid, ovo-ellipsoid, ellipsoid; or pileal elements clavate, lagenifrom, cylindrico-clavate, utriform ..... ***Leucocoprinus* species 3**
11. Pileus more than 20 mm diameter; spores 8.5-12.5 × 6-8 µm, amygdaliform; pileal elements fusoid or cylindrical ..... ***Leucocoprinus* species 4**
12. Basidiomata white; stipe densely fibrillose to granular or wooly-floccose; spores 6-12 × 5-7 µm ..... ***Leucocoprinus cretaceus***
12. Basidiomata yellow; stipe not densely fibrillose or wooly floccose; spores 8-11.5 × 5-7 µm ..... ***Leucocoprinus birnbaumii***
13. Pileus non-striate; stipe turning rust brown to reddish brown on bruising; spores 5-9 × 3-4.5 µm, amygdaliform; cheilocystidia with apical prolongations; pileal covering with cylindrico-clavate elements..... ***Leucocoprinus jubilaei***

13. Pileus sulcate-striate; stipe colour unchanging; spores not amygdaliform; cheilocystidia without apical prolongations; pileal covering with ovoid, ellipsoid or globose elements **14**

14. Pileus with yellowish squamules; spores 5-10.5 × 3.5-6 µm; pileal covering with ovoid, ellipsoid or globose cells terminated by short cylindrical elements ..... ***Leucocoprinus submontagnei***

14. Pileus with dark brown squamules; spores 5-6.5 × 3.5-4.5 µm; pileal covering composed entirely of globose elements ..... ***Leucocoprinus straminellus***

Leucocoprinus holospilotus (Berkeley & Broome) Reid in Mycological Research 94: 648 (1990)

Agaricus holospilotus Berkeley & Broome in Journal of Linnean Society 11: 497 (1871)

Lepiota holospilota (Berkeley & Broome) Saccardo in Sylloge Fungorum 5:53 (1887)

Leucoagaricus holospilotus (Berkeley & Broome) Bon in Documents Mycologiques 23: 33 (1993)

Fig. 26. A-F; Pl. 25.

Basidiomata small to somewhat medium-sized, all parts turning pistachio green (28C4) to greyish green (28D4, 28E5) on exposure to ammonia fumes and yellow (2A4) to brownish orange (6C6) on bruising. **Pileus** 30-102 mm diam., paraboloid when young, becoming convex to broadly convex on maturity and applanate with age, umbonate at the disc; surface finely sulcate-striate towards margin, granular to pruinose at the disc, furfuraceous elsewhere, with brownish orange (7C3, 7C4) to reddish brown (7E6, 7E7, 8E6, 9D6) fibrillose squamules scattered on a whitish

background; squamules sparser and appressed towards margin and concentrated and recurved towards the disc; margin initially incurved, becoming straight, entire. **Lamellae** free, white to yellowish white (1A2), moderately crowded to crowded, up to 7 mm wide, with lamellulae in 2-4 tiers; edge finely fimbriate under a lens, finely dotted grey. **Stipe** 33-145 × 4-17 mm, central, terete, expanding towards base but extreme base slightly pointed, solid, becoming fistulose and finally hollow; surface whitish with a reddish white (7A2) to greyish tinge, dotted with fine reddish brown (8E6, 9D6) squamules towards the base, fibrillose to rather villose; base arising from a white mycelium. **Annulus** superior, membranous, ascending, fixed, white, with dense reddish brown (8E6) to dark reddish brown (9D6) squamules below and at the bilipped rim. **Context** up to 2 mm thick, white, turning brownish orange (6C6) to light brown (6D6) on exposure in some specimens. **Odour** not distinctive. **Spore-print** white.

Spores 7-13 × 5-8 (9.5 ± 0.89 × 7 ± 1.41) µm, Q = 0.8-1.7, Qm = 1.5, ellipsoid to broadly ellipsoid, rarely ovoid, with a germ-pore up to 1 µm broad, hyaline, with refractive guttules, thick-walled, smooth, dextrinoid, metachromatic in cresyl blue, cyanophilic in cotton blue. **Basidia** 15-29 × 7-12 µm, clavate, with guttulate contents, bearing 4 sterigmata up to 4 µm long. **Lamella-edge** sterile. **Cheilocystidia** 16-41 × 9-17 µm, lageniform, utriform, or broadly clavate with a subcapitate apex or with a flexuose or moniliform apical prolongation up to 20 µm long, hyaline to pale grey or grey, thin-walled. **Pleurocystidia** absent. **Lamellar trama** subregular;

hyphae 2-15 µm wide, inflated, hyaline, septate, thin-walled, inamyloid. **Subhymenium** cellular. **Pseudoparaphyses** well-developed. **Pileal trama** interwoven; hyphae 5-25 µm wide, inflated, hyaline, thin-walled, inamyloid. **Pileal covering** a cutis disrupted by trichodermial patches of ascending or erect terminal elements; terminal elements 20-220 × 7-26 µm, mostly lageniform with prominent and elongated irregular prolongations reaching up to 150 µm long and with tapering, pointed apex, rarely clavate with or without apical prolongations, with pale brown to grey plasmatic pigment, thin-walled. **Stipe covering** a cutis of repent or rarely disrupted 2-10 µm wide, thin-walled, hyaline hyphae with lageniform or clavate, 40-90 × 11-17 µm terminal elements often with long, flexuose and tapering apical prolongation. All hyphae lack clamp-connections.

Habitat: On bark of living trees or on dead wood, solitary and in caespitose clusters.

Known Distribution: AFRICA, the Lesser Antilles, EUROPE, India, Sri Lanka.

Collections examined — Malappuram District, Calicut University Campus: 10 June 2004, AK53; 9 July 2004, AK65; 29 June 2006, AK 404; 30 June 2006, AK405; 10 July 2006, AK 416; 11 July 2006, AK404a; Calicut District, Pavangad: 12 June 2005, AK257; Nallalam: 28 June 2006, AK402.

The Kerala collections agree with the description of *Lepiota holospilotus* (Berkeley & Broome) Saccardo, given by Pegler (1972, 1986), based on the type materials of two species (holotypes of *Agaricus holospilotus* Berkeley & Broome, Thwaites 1171 and *A. biornatus* Berkeley & Broome, Thwaites 1168), originally described by Berkeley & Broome from Sri Lanka in 1869, except for the slightly larger spore dimensions. Pegler justified uniting *L. holospilotus* and *L. biornatus* (Berkeley & Broome) Saccardo under a single epithet by stating that the two are identical in all macroscopic and microscopic characters, but for the smaller basidiome size of the former. A restudy of the type materials along with the icon and the original diagnosis of the two species, prompted Reid (1990) to transfer the specific epithet of *L. holospilotus* to *Leucocoprinus* and to follow Pegler in accepting their conspecificity, with a remark that considerable confusion exists and that a study of more materials from Sri Lanka is required to establish the precise identity of the species.

Collections from Kerala, displayed a continuous range of variations in both macroscopic and microscopic characters and in the light of these observations, the distinction of the materials into two species cannot be supported. Basidioma size, the major and perhaps the only demarcating character between *L. holospilotus* and *L. biornatus* (as opined by Pegler 1972, 1986) represent a very vague and thin boundary of distinction. Hence the name *L. holospilotus* is accepted here for the present material, in the sense of Pegler and Reid. This taxon has earlier been reported from Kerala by Vrinda *et al.* (2003) as *Leucocoprinus biornatus* (Berkeley & Broome)

Locquin with descriptions almost identical with the present collections except for an unchanging context colour. A very close *L. caldariorum* Reid differs in having a well-developed spreading annulus, broadly amygdaliform spores and hymeniform layer of pileal surface overtopped with clavate to lanceolate elements. *Leucocoprinus meleagris* (Sowerby) Locquin differs in having a context that becomes red on exposure, an indistinct annulus and with cylindrical and narrowly clavate to clavate elements of pileal covering. *Leucocoprinus bresadolae* (Schulzer) Moser could be differentiated on account of its twisted and ribbon-like elongated pileal elements and by the lack of any differentiated elements on the stipe surface. However, a wide overlap of range of characters could be noticed between *L. holospilotus*, *L. caldariorum*, *L. meleagris* and *L. bresadolae* and more morphological and molecular investigations are required for a better understanding of their taxonomic status and relationships.

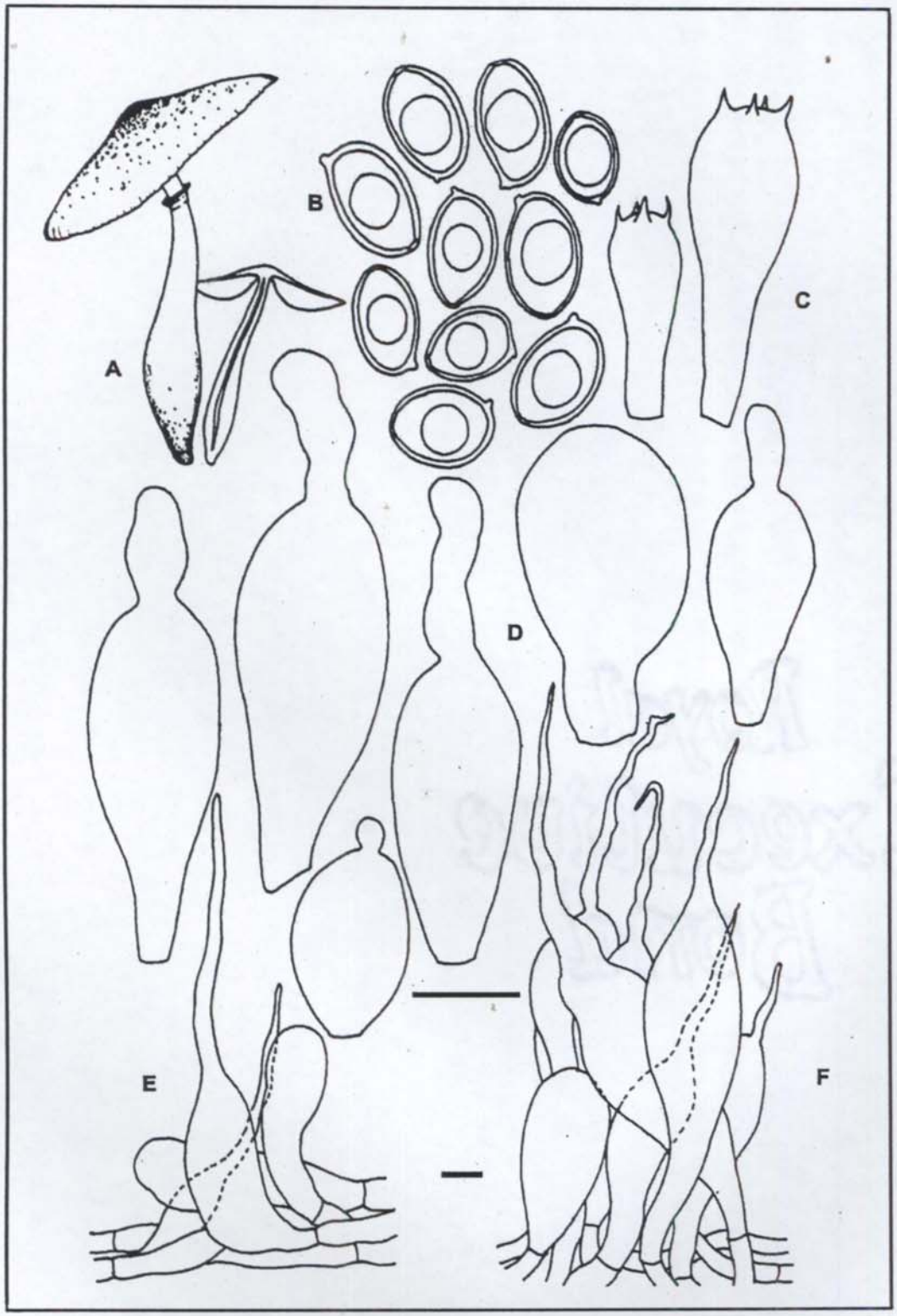


Figure 26. *Leucocoprinus holospilotus* **A.** Habit x 1 **B.** Spores **C.** Basidia **D.** Cheilocystidia **E.** Stipe covering **F.** Pileus covering. Bars = 10 µm.

Leucocoprinus lacrymans T. K. A. Kumar & Manimohan in Mycotaxon 90 (2): 393-397 (2004)

Fig. 27. A-F; Pl. 26.

Basidiomata small to somewhat large and robust, all parts turning greenish grey (28D2) on reaction with ammonia fumes and pale reddish brown (8D8) on bruising. **Pileus** 30-83 mm diam., at first truncate-cylindrical, then conico-campanulate to convex, finally becoming applanate often with a more or less distinct obtuse umbo; surface white, dotted with minute, appressed, cinnamon (6D6) to rust brown (6E8) squamules that are denser towards the umbo and sparse towards the margin, densely granulose-squamose to somewhat velutinate at the umbo; sulcate-striate towards margin, beaded with golden yellow (5B7) to reddish brown (8D8) watery exudates; margin initially incurved and entire, becoming plane and fissile with age. **Lamellae** free but not attached to a collarium, moderately crowded, ventricose, thin, up to 4 mm wide, initially white, turning yellowish white (1A2), finally reddening with age or on drying, with lamellulae in 2-3 tiers; edge finely fimbriate, tinted greyish on mature specimens. **Stipe** 40-120 × 5-6 mm, central, terete, almost equal or slightly tapering towards the apex, hollow; surface white to orange white (5A2, 5A3), darkening (6E6, 6E7, 7D5) with age, rather velutinous to villose when young, somewhat appressed-fibrillose when old, beaded with golden yellow (5B7) to reddish brown (8D8) watery exudates; base with white mycelial cords. **Annulus**

superior, white, membranous, evanescent, usually disrupting without trace. **Context** up to 3 mm thick, initially white, turning orange white (5A2) to pale orange (5A3) and finally greyish orange (5B3, 5B4) on prolonged exposure. **Odour** not distinctive. **Spore-print** white to yellowish white.

Spores 5-13 × 4.5-11 (8.63 ± 1.84 × 6.5 ± 1.37) µm, Q = 1.0-1.6, Qm = 1.33, broadly ellipsoid, ovoid or subglobose, with a distinct germ-pore (up to 1.5 µm broad), hyaline, with refractive guttules and a thick complex wall, smooth, dextrinoid, distinctly metachromatic in cresyl blue, cyanophilic in cotton blue. **Basidia** 20-28 × 8-12.5 µm, clavate to broadly clavate, with guttulate contents, bearing 4 sterigmata less than 4 µm long. **Lamella-edge** sterile. **Cheilocystidia** 10-126 × 4-8 µm, narrowly cylindrical to flexuose, with an obtuse apex, often in tufts, thin-walled, hyaline or with pale to dark brown contents. **Pleurocystidia** absent. **Lamellar trama** regular, of thin-walled, hyaline hyphae, 3-7 µm wide, inflated up to 24 µm. **Subhymenium** cellular. **Pseudoparaphyses** abundant. **Pileal trama** interwoven; hyphae 3-20 µm wide, thin-walled, hyaline, inamyloid. **Pileal covering** a disrupted cutis with trichodermial patches of ascending or erect elements, 60-125 × 4-8 µm, narrowly cylindrical or somewhat flexuose, with obtuse tips, thin-walled, with brown granular contents; entirely trichodermial at the disc. **Stipe covering** a disrupted cutis of thin-walled, hyaline to grey-coloured hyphae with trichodermial patches of ascending or erect elements; terminal elements up to 100 µm long, 2-5 µm wide, narrowly cylindrical to somewhat flexuose, with obtuse apices. All hyphae lack clamp-connections.

Habitat: On soil and decaying leaf litter around the base of coconut trees, solitary or in clusters.

Known Distribution: Only from the type locality.

Collections examined — Calicut District, Puthiyangadi: 28 August 2003, AK1; 9 April 2004, AK17; 11 April 2004, AK17a; 27 April 2004, AK18; 27 April 2004, AK18a; 28 April 2004, AK18b; 4 May 2004, AK18c; 8 May 2004, AK18d; 14 July 2004, AK67; 10 April 2005, AK209; Pavangad: 3 November 2004, AK169; Malappuram District, Kondotty: 4 November 2004, AK170.

Leucocoprinus lacrymans is characterized by small to medium-sized whitish basidiomata dotted with fine brownish squamules and drops of golden yellow to reddish brown exudates, greenish grey colouration of basidiomata on reaction with ammonia fumes, gradual colour change to pale reddish brown on bruising, a white context turning orange white to pale orange and finally greyish orange on prolonged exposure, spores showing a wide range of size and shape and conspicuously elongate and flexuous chielocystidia, and cylindrical pileal elements. The species is considered under *Leucocoprinus* because of the abundant development of pseudoparaphyses in the hymenium.

This species is clearly related to the *Leucocoprinus badhamii* complex (Reid 1990) comprising species which redden on bruising or become green

in ammonia fumes. The closest in the complex seems to be *Leucocoprinus meleagris* (Sowerby) Locquin, known to be widely distributed in both temperate and tropical regions (Pegler 1977, 1983; Manjula 1983; Reid 1990; Vellinga 2001b). These two species have a number of macroscopical and a few microscopical similarities including the size and shape of the spores. However, the shape of the cheilocystidia and elements comprising the scales on the pileal surface and covering of the stipe in *L. lacrymans* is always cylindrical while it is never cylindrical but clavate, fusoid or lanceolate often with a distinct apical prolongation in *L. meleagris*. Also, on bruising, the basidiomata of *L. lacrymans* turn pale reddish brown while those of *L. meleagris* turn intensely red. On exposure, the context of *L. lacrymans* changes colour from white through orange white to pale orange while that of *L. meleagris* discolours through lemon yellow to orange red. In addition, the basidiomata of *L. lacrymans* always exude droplets of a golden yellow to reddish brown watery fluid, a feature not known in *L. meleagris* and related species. The Sri Lankan species, *Leucocoprinus holospilotus* (Berkeley & Broome) Reid, closely related to *L. meleagris*, is characterized by unchanging colour of flesh, smaller spore dimensions, clavate or broadly lanceolate cheilocystidia with a mucronate apex and pileal scales comprising of short ovate or broadly lanceolate cystidiiform elements. *L. caldariorum* Reid, another species similar in appearance and habitat to *L. meleagris*, has a well-developed spreading annulus, broadly amygdaliform spores, ovate, clavate or lanceolate cheilocystidia frequently with apical prolongation and pileal surface with numerous short and squat hairs.

Although not included under the *Leucocoprinus badhamii* complex (presumably for want of data on response of its basidiomata to ammonia), *Leucocoprinus zeylanicus* (Berkeley) Boedijn is a very closely related species with a known distribution in Africa, Sri Lanka, New Zealand (Guzmán & Guzmán-Dávalos 1992) and India (Vrinda *et al.* 2003). The reports on the species from India are based on collections from Kerala State, with descriptions that also lack data on reaction with ammonia. A critical comparative study of *L. lacrymans* with the representative Kerala collections of *L. zeylanicus* (TBGT 2069, TBGT 2091, TBGT 2157, TBGT P5345, deposited at TBGT) collected by Vrinda *et al.*, combined with their descriptions, and also with those given by Pegler (1977, 1986) based on materials collected from Africa and Sri Lanka, confirms a clear distinction. The following are the major differences that distinguish *L. zeylanicus*: 1) glabrous stipe; 2) absence of any noticeable, golden yellow to reddish brown watery exudates on both pileal and stipe surface; 3) smaller spores with a small germ-pore; 4) vesiculose, ovate, clavate, or lanceolate elements of pileal covering, frequently with apical prolongations; and 5) elements of stipe covering ventricose-fusoid to lageniform, with a long slender neck.

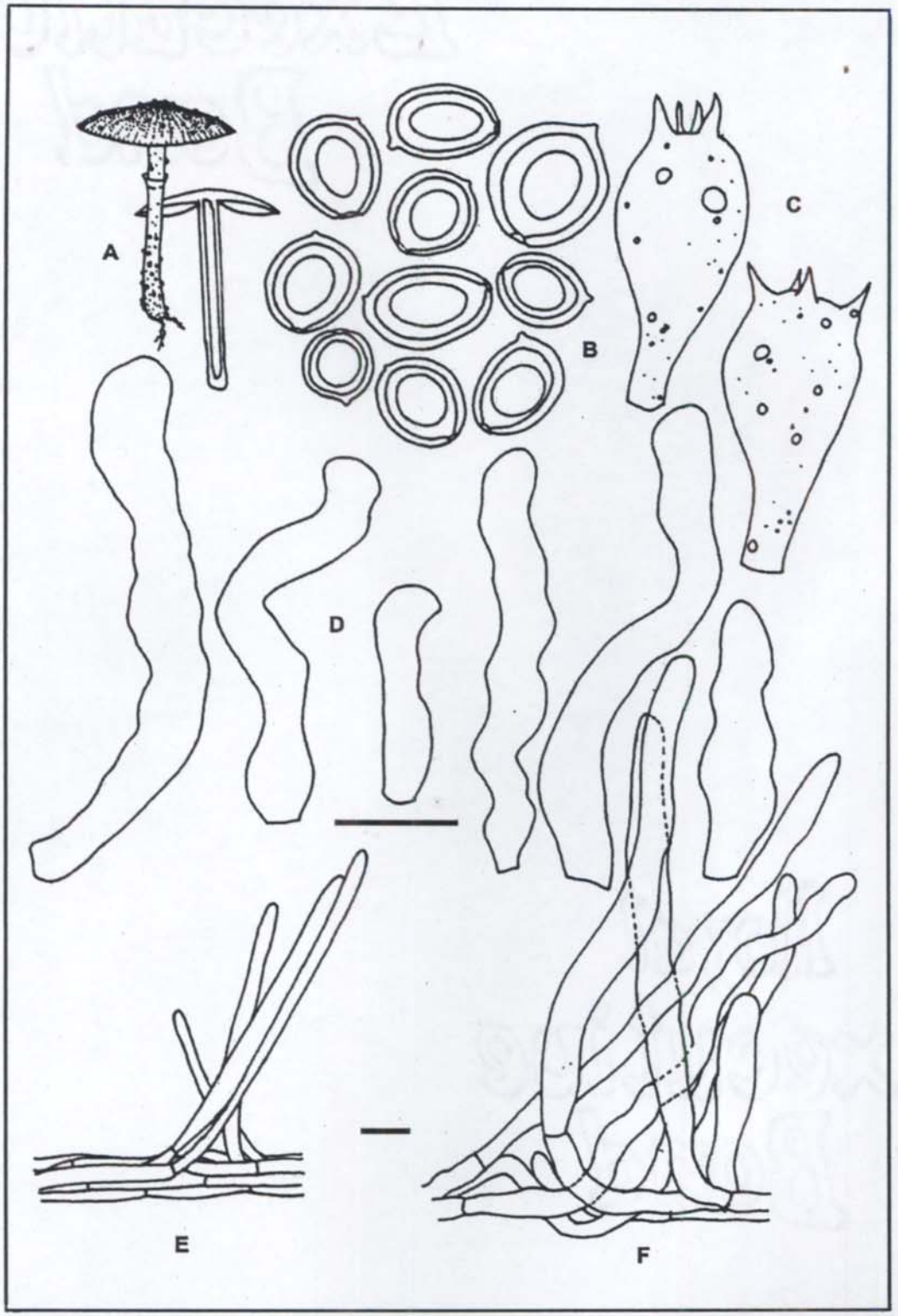


Figure 27. *Leucocoprinus lacrymans* **A.** Habit x 1 **B.** Spores **C.** Basidia **D.** Cheilocystidia **E.** Stipe covering **F.** Pileus covering. Bars = 10 µm.

Plate 25. *Leucocoprinus holospilotus* x 2

Plate 26. *Leucocoprinus lacrymans* x 1

Leucocoprinus fragilissimus (Berkeley & Curtis) Patouillard in Essai taxonomique sur les familles et les genres des Hyménomycètes: 171 (1900)

> *Hiatula fragilissima* Ravenos. In Berkeley & Curtis in Annals and Magazin of Natural History series II, 12: 422 (1853) (genus name unpublished)
>
> *Lepiota fragilissima* (Ravenos) Morgan in Journal of Mycology 13: 5 (1907)
>
> *Agaricus fragilissimus* (Ravenos) Hennings in A. Engler & K. Prantl (eds), Die natürlichen Pflanzenfamilien, 1, 1**: 263 (1900)
>
> - *Agaricus licmophorus* Berkeley & Broome in Journal of Linnean Society 11: 500 (1871)
>
> *Lepiota licmophora* (Berkeley & Broome) Saccardo in Sylloge Fungorum 5: 44 (1887)
>
> *Hiatula licmophora* (Berkeley & Broome) Petch in Annals of the Royal Botanic Garden, Peradeniya 4: 385 (1910)
>
> *Leucocoprinus licmophorus* (Berkeley & Broome) Patouillard in Bulletin trimestriel de la Société mycologique de France 29: 216 (1923)

Fig. 28. A-D; Pl. 27. A. & B.

Basidiomata small to medium-sized, extremely fragile. **Pileus** 15-30 mm diam., ellipsoid when very young, becoming convex to broadly convex and finally applanate with an indistinct umbo; surface pastel yellow (1A4), greyish yellow (1B5, 1E7) at the disc, fibrillose, distinctly sulcate-striate towards the margin from the disc; margin initially incurved, later straight, entire. **Lamellae** free, pastel yellow (1A4), close to moderately crowded, up to 2 mm wide, with lamellulae in 1-2 tiers; edge finely fimbriate under a lens, concolorous with the sides. **Stipe** 80-130 x 2-3 mm (up to 7 mm wide at the base), central, terete, almost equal, somewhat bulbous at the base, hollow;

surface concolorous with the pileus, fibrillose; base arising from whitish mycelium. **Annulus** superior, membranous, movable, evanescent. **Context** less than 1 mm thick, pastel yellow (1A4). **Odour** not distinctive. **Spore-print** not obtained.

Spores 9.5-15 x 7-11 (11.5 ± 1.3 × 9.2 ± 1.04) µm, Q = 0.8-1.4, Qm = 1.3, ovoid to broadly ellipsoid, often constricted apically into a short cylindric region, terminated by a truncate germ-pore up to 1.5 µm wide and plugged with a lens-cap-like exudate, hyaline, with refractive guttules, thick-walled, smooth, dextrinoid, metachromatic in cresyl blue, cyanophilic in cotton blue. **Basidia, Cheilocystidia** and **Pleurocystidia** not observed. **Lamellar trama** subregular; hyphae 3-20 µm wide, inflated, hyaline, thin-walled, inamyloid. **Subhymenium** cellular. **Pseudoparaphyses** abundant and well-developed. **Pileal trama** interwoven; hyphae 5-32 µm wide, inflated, hyaline, thin-walled, inamyloid. **Pileal covering** a disrupted layer composed of a mixture of hyaline, irregular and closely arranged sphaerocysts, 15-60 µm diam., and irregular chains of thin-walled, cylindric elements, 43-92 x 5-13 µm wide. **Stipe covering** a differentiated cutis of rather narrow hyphae; hyphae 1.5-5 µm wide, septate, hyaline, thin-walled. All hypahe lack clamp-connections.

Habitat: On decaying leaf litter, solitary and scattered.

Known Distribution: AFRICA, the Lesser Antilles, Brazil, Galapagos, EUROPE, India, Japan, Sri Lanka, Thailand, USA, Venezuela

Collections examined — Calicut District, Peruvannamuzhi: 25 May 2004, AK35, 27 May 2004, AK35a; Wayanad District, Muthanga: 2 June 2005, AK224; 2 June 2005, AK240.

This is a remarkable species readily recognized in the field because of its extremely fragile and short-lived basidiomata. Microscopically the species can be easily distinguished by the ovoid to broadly ellipsoid spores that are often constricted apically into a short cylindric region terminated by a wide germ-pore plugged with a hyaline-exudate-cap, and the pileal surface with closely packed sphaerocysts.

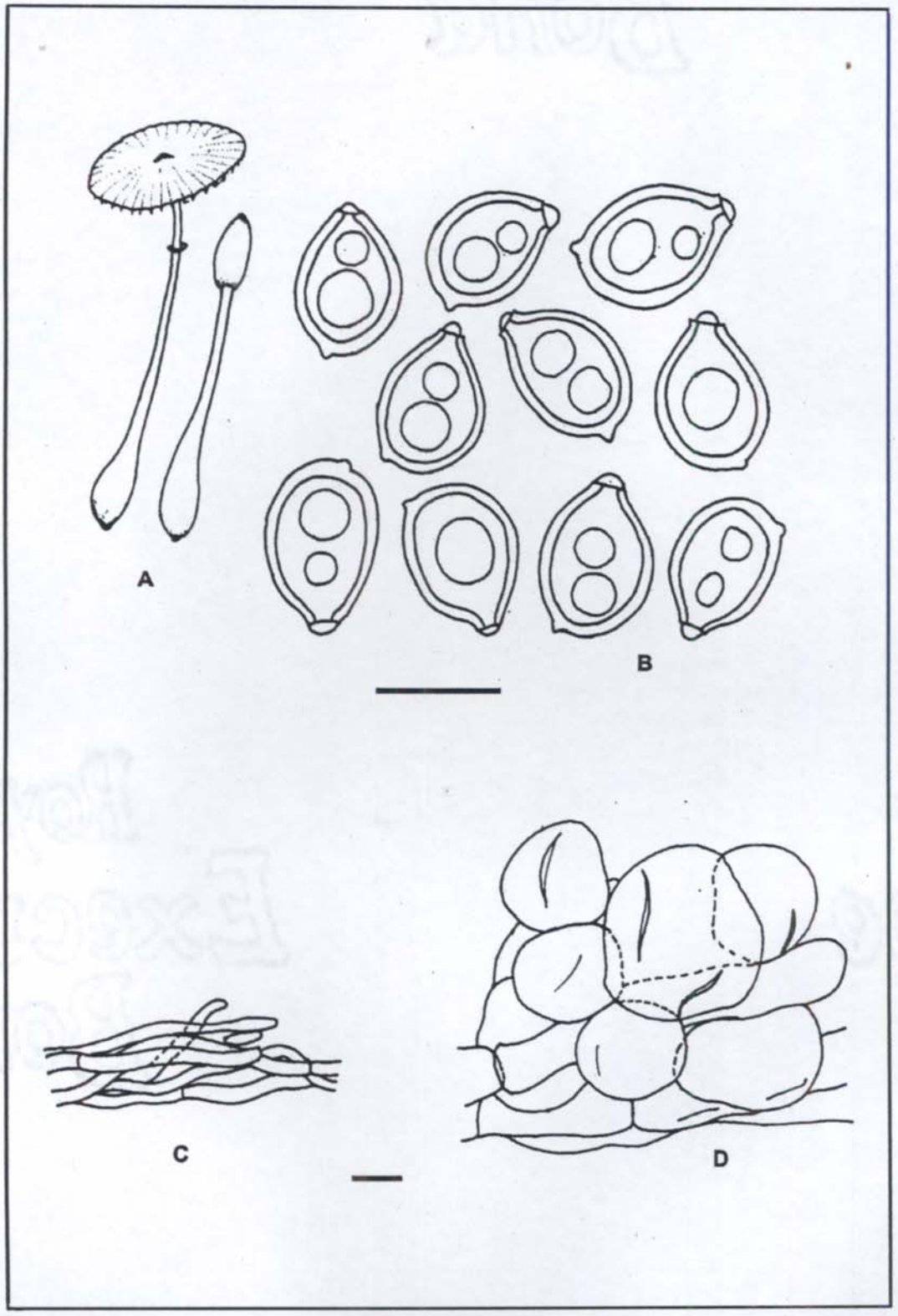


Figure 28. *Leucocoprinus fragilissimus* **A.** Habit x 1 **B.** Spores **C.** Stipe covering **D.** Pileus covering. Bars = 10 µm.

Leucocoprinus ianthinus (Cooke) Locquin in Bulletin mensuel de la Société Linnéenne de Lyon 14: 94 (1945)

Agaricus ianthinus Cooke in Grevillea 16: 101 (1888), non *Agaricus ianthinus* Fries (1821)

Lepiota ianthina (Cooke) Saccardo in Sylloge Fungorum 9: 10 (1891)

Leucocoprinus ianthinus (Cooke) Mohr in Boletus 18: 48 (1992) (superfluous)

- *Lepiota lilacinogranulosa* Hennings in Verhandlungen des Botanischen Vereins für die Provinz Brandenburg 40: 145 (1898)

Leucocoprinus lilacinogranulosus (Hennings) Locquin in Bulletin mensuel de la Société Linnéenne de Lyon 12: 94 (1943)

Leucocoprinus lilacinogranulosus (Hennings) Bon *et al.* in Documents mycologiques 19: 53 (1989) (superfluous)

Hiatula cepaestipes variety *lilacinogranulosus* (Hennings) Heim & Romagnesi in Bulletin trimestriel de la Société mycologique de France 50: 184 (1934)

Fig. 29. A-F; Pl. 28.

Basidiomata small and somewhat fragile. **Pileus** 17-23 mm diam., conico-convex, conico-campanulate or broadly convex, distinctly umbonate at the disc; surface dull white to orange grey (5B2) or greyish orange (5B3) with scattered greyish brown (8F3, 10F3) squamules which are concentrated towards disc and sparser towards the margin, fibrillose, rather furfuraceous, distinctly sulcate-striate towards the margin; margin initially incurved, later straight, crenate. **Lamellae** free, initially whitish, becoming dull white to yellowish white (4A2) or orange grey (5B2), crowded, up to 2 mm wide, with lamellulae in 2-3 tiers; edge finely fimbriate under a lens, concolorous with the sides. **Stipe** 46-63 × 2 mm (5 mm wide at the base), central, terete,

almost equal above annulus, expanding towards base, fistulose, becoming hollow with age; surface dull white to orange grey (6B2), becoming greyish brown (7E3, 8E3) on bruising or with age, fibrillose-villose to rather tomentose; base arising from a dull white mycelium. **Annulus** inferior to almost central, membranous, initially fixed, becoming movable with age, fibrillose below. **Context** up to 1 mm thick, orange grey (5B2) to greyish brown (8F3). **Odour** not distinctive. **Spore-print** not obtained.

Spores 8-11 × 5.5-7 (9.9 ± 0.58 × 6.4 ± 0.44) µm, Q = 1.4-1.7, Qm = 1.5, ovoid in top view, ellipsoid to subamygdaliform in side view, with a germ-pore up to 1 µm wide and covered by a lens-cap-like exudate, hyaline, with refractive guttules, thick-walled, smooth, dextrinoid, metachromatic in cresyl blue, cyanophilic in cotton blue. **Basidia** 16-36 × 9-11 µm, cylindrico-clavate to clavate, with guttulate contents, bearing 4 sterigmata up to 4.5 µm long. **Lamella-edge** sterile. **Cheilocystidia** 32-65 × 21-30 µm, inflated-clavate to ovoid, collapsing on drying, hyaline, thin-walled. **Pleurocystidia** absent. **Lamellar trama** subregular; hyphae 3-11 µm wide, septate, hyaline, thin-walled, inamyloid. **Subhymenium** cellular. **Pseudoparaphyses** abundant and well-developed. **Pileal trama** parallel to slightly interwoven; hyphae 3-22 µm wide, inflated, septate, hyaline, thin-walled, inamyloid. **Pileal covering** a disrupted cutis of filamentous hyphae with ascending or erect, easily disrupting chains of elements that are cylindrical, ellipsoid or clavate in shape and 26-95 × 7-22 µm in size intermixed with sphaerocysts that are 17 µm in diam.; all elements thin-walled and with pale grey to grey pigments;

entirely trichodermial at the disc. **Stipe covering** a cutis disrupted by ascending cylindrical elements, 26-85 × 5-9 µm, thin-walled, with hyaline or pale grey plasmatic pigment. All hypahe devoid of clamp-connections.

Habitat: On soil in grass lands, solitary or scattered.

Known Distribution: EUROPE, USA

Collections examined — Kannur District, Neeliyarkottam: 16 October 2004, AK140; Malappuram District, Calicut University Campus: 20 October 2004, AK142; 10 November 2004, AK142a; 16 November 2004, AK142b.

Leucocoprinus ianthinus could be easily recognized in the field from its almost fragile basidiomata with a thin, dull white to greyish pileus covered with scattered greyish brown squamules. The somewhat large spores are ellipsoid to amygdaliform, cheilocystidia are inflated clavate to ovoid and pileal covering consists of cylindrical, ellipsoid or clavate elements intermixed with sphaerocysts.

This species is better known as *Leucocoprinus lilacinogranulosus* (Hennings) Locquin and the name *L. ianthinus* has been used here following Bon (1996). Reid (1989) neither substantiated Bon's view in clear terms, nor indicated any decisive evidences to distinguish the taxa under the two epithets, even after a re-examination of the holotype of *L. ianthinus*. The synonymy forwarded by Bon is also found accepted by Vellinga (2001c).

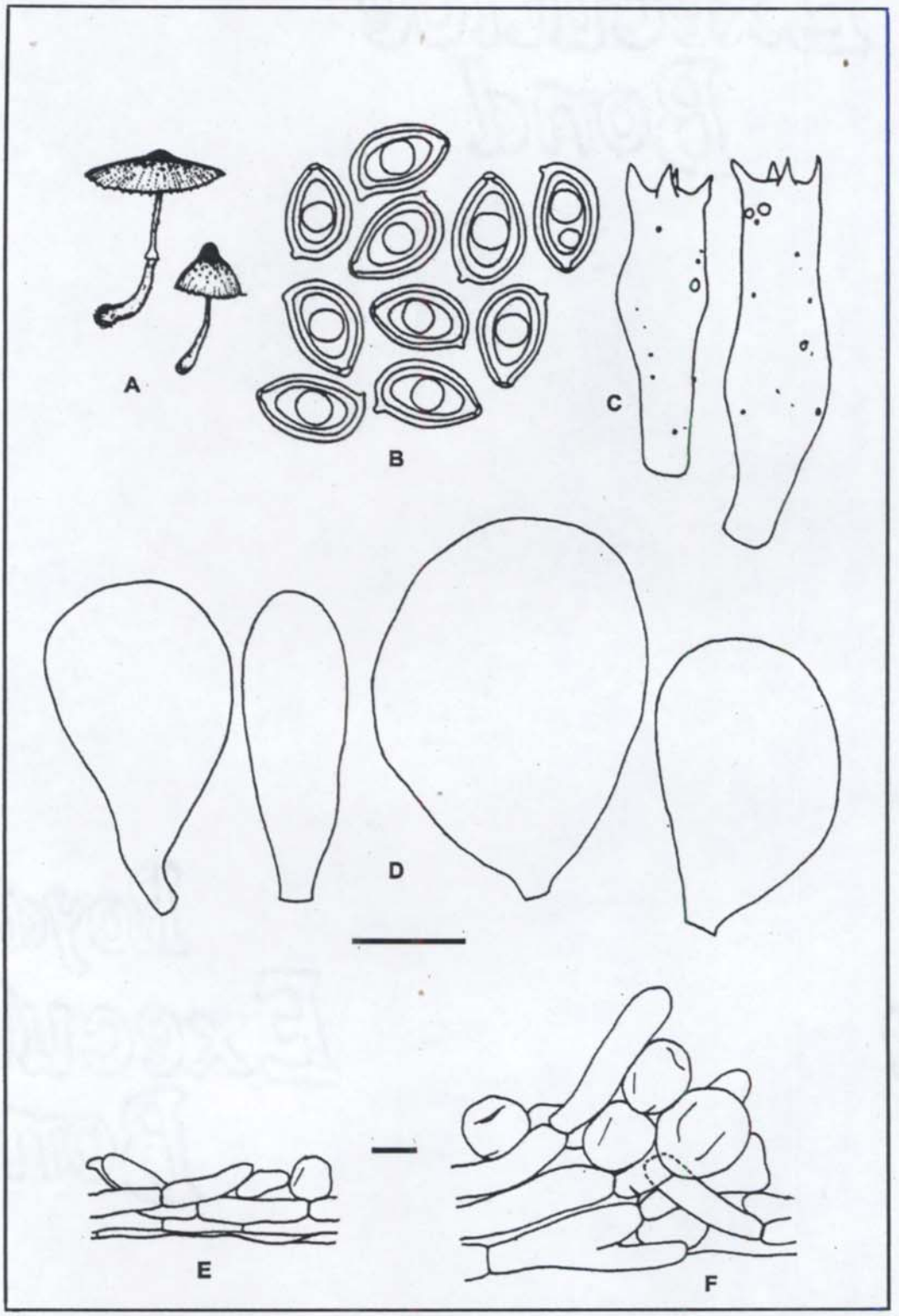


Figure 29. *Leucocoprinus ianthinus* **A.** habit x 1 **B.** Spores **C.** Basidia **D.** Cheilocystidia **E.** Stipe covering **F.** Pileus covering. Bars = 10 µm

Plate 27. A. *Leucocoprinus fragilissimus* x 2.5, **B.** x 2

Plate 28. *Leucocoprinus ianthinus* x 3

***Leucocoprinus* species 1**

Fig. 30. A-F; Pl. 29. A & B.

Basidiomata small to somewhat medium-sized. **Pileus** 20-60 mm diam., convex to campanulate when very young, becoming convex to broadly convex and finally conico-campanulate, mostly with a prominent conical umbo, the acuteness of which become pronounced with age; surface dull white for the most part, yellowish white (2A2), towards margin, cinnamon brown (6D6) at the umbo, fibrillose to rather tomentose, with scattered cottony-floccose squamules concentrated more towards the disc and less towards margin, distinctly sulcate-striate towards margin; margin initially incurved, becoming straight, entire to finely serrate. **Lamellae** free, whitish, turning yellowish brown (5D5) with age, close to crowded, up to 10 mm wide, with lamellulae in 1-4 tiers; edge finely fimbriate to denticulate, concolorous with the sides. **Stipe** 30-55 x 3-5 mm (up to 10 mm at the base), central, terete, expanding towards base, solid when very young, becoming fistulose to hollow with age; surface whitish with a reddish grey (7B2) tinge, finally turning greyish brown (6D3) with age, turning 'titian red' (7D6) on bruising, pruinose to rather velutinous; base arising from whitish mycelium. **Annulus** superior, membranous, fixed, with dark brown (6E7) squamules on the upper side. **Context** less than 2 mm thick, whitish. Stipe context changing to 'titian red' (7D6) on exposure. **Odour** not distinctive. **Spore-print** white.

Spores 8-11 x 6-8 (10 ± 1.4 × 7 ± 0.65) µm, Q = 1-1.8, Qm = 1.4, ovoid to ellipsoid with a truncated base and a germ-pore up to 1 mm wide plugged by a lens-cap-like exudates, hyaline, with refractive guttules, thick-walled, smooth, dextrinoid, distinctly metachromatic in cresyl blue, cyanophilic in cotton blue. **Basidia** 21-33 x 10-13.5 µm, clavate, with guttulate contents, bearing 4 sterigmata up to 5 µm long or occasionally 1-2 abnormally elongated sterigmata up to 16 µm long and 3 µm wide. **Lamella-edge** sterile. **Cheilocystidia** 11-70 x 8-18 µm, lageniform or utriform, with subcapitate or long and flexuose or moniliform apex, hyaline to pale grey, thin-walled. **Pleurocystidia** absent. **Lamellar trama** subregular; hyphae 2-6 µm wide, inflated up to 10 µm, hyaline, thin-walled, inamyloid. **Subhymenium** cellular. **Pseudoparaphyses** abundant. **Pileal trama** interwoven; hyphae 2-20 µm wide, inflated, hyaline, thin- to slightly thick-walled, inamyloid. **Pileal covering** a loose disrupted cutis forming trichodermial patches of ascending or erect chains of somewhat inflated, cylindric to subglobose elements, 15-70 x 5-20 µm, hyaline and slightly thick-walled. **Stipe covering** a trichodermium of erect cylindrical, lageniform, flexuose elements, 20-70 x 3-8 µm, slightly thick-walled, hyaline or pale grey, with obtuse or acuminate apices. All hypahe lack clamp-connections.

Habitat: On the bark of living trees or on decaying wood, solitary or in caespitose groups.

Known Distribution: Only from the type locality.

Collections examined — Malappuram District, Calicut University Campus: 21 July 2004, AK72; 10 August 2004, AK72a; 9 August 2004, AK87; 10 August 2004, AK87a; 12 August 2004, AK87b; 16 August 2004, AK87c; 20 August 2004, AK87d; 22 August 2004, AK72b; 17 July 2006, AK417.

This is a very distinct species with a conspicuously acute umbo, whitish pileus with sulcate striations towards the margin, whitish stipe context turning titian red on bruising, membranous annulus with dark brown squamules on the upper side, large ovoid to ellipsoid spores with a conspicuous germ-pore, lageniform or utriform cheilocystidia with moniliform apex, pileal covering entirely made of loosely attached subglobose to cylindric elements and a trichodermial stipitipellis with erect cylindrical, lageniform or flexuose elements. The presence of distinct striations on the pileus and abundant pseudoparaphyses in the hymenium confirms its position inside the genus *Leucocoprinus*.

Although the species exhibit characters that suggest a close relationship with members of the *Leucocoprinus badhamii* complex, including a reddish colour change of the stipe context upon bruising, the consistent negative response to ammonia (species of the group responds positively by a greenish colour change or exceptionally pink colouration in the case of *L. croceovelutinus* Bon & Boiffard), even after tests with several basidiomata at different developmental stages, indicates its uniqueness. In the key to the 'badhamii complex' by Reid (1990), *L. jubilaei* (Josserand) Wasser is the only member that shows no reaction to ammonia. However, in the same

paper Reid mentions that the chemical response of that species is variable and remarkably, the reaction of materials of the same species studied by Babos (1979) is recorded as positive. *Leucocoprinus jubilaei*, a small species also encountered in Kerala, could be easily distinguished from the present collections by means of the highly deviant macroscopic and microscopic characters.

The peculiar nature and composition of the pileal covering, along with several other characters distinguishes the species from other related species. Since a comparable species description is not available in the literature, the present materials are considered hitherto undescribed and new.

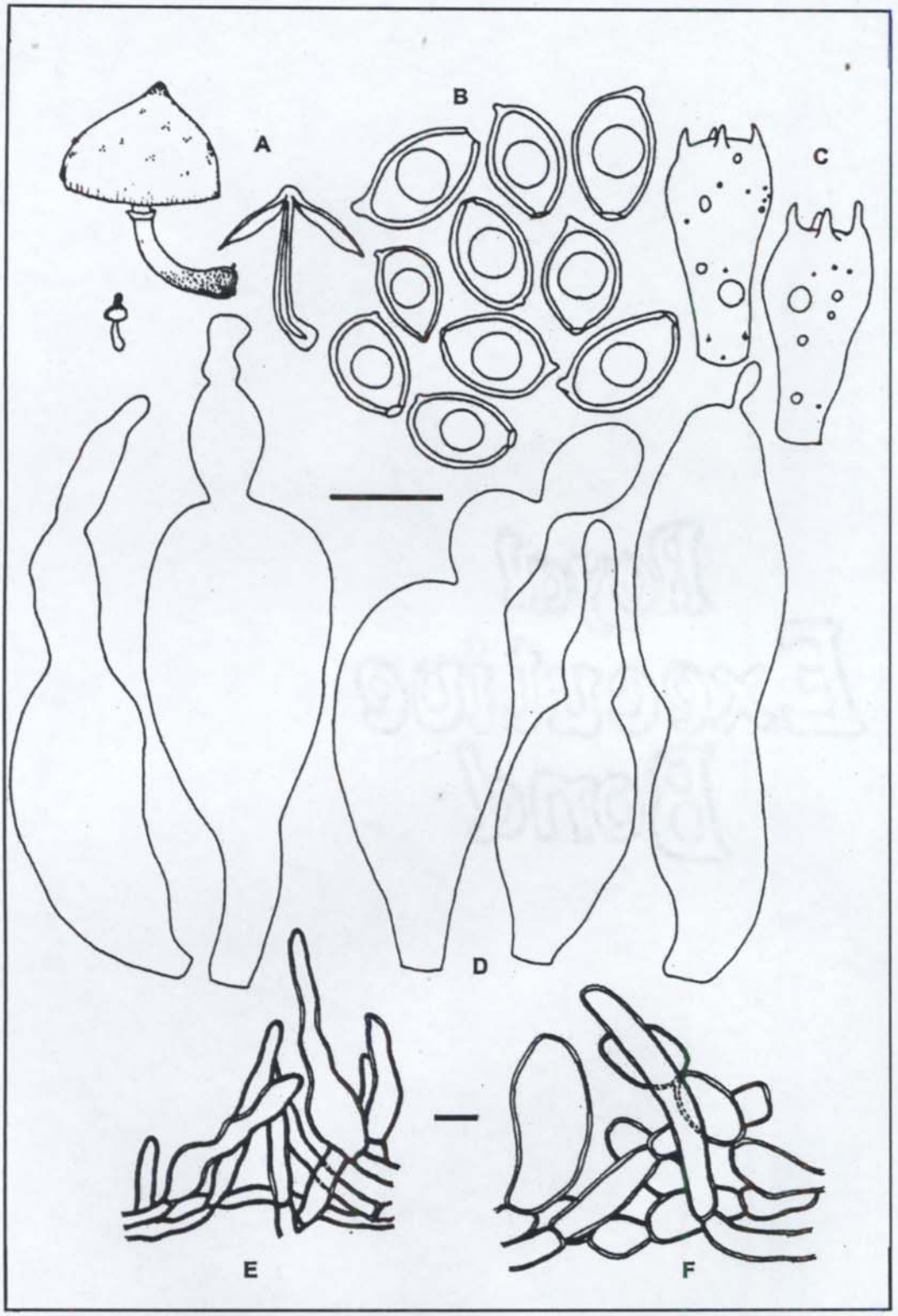


Figure 30. *Leucocoprinus* species 1 **A.** Habit x 1 **B.** Spores **C.** Basidia **D.** Cheilocystidia **E.** Stipe covering **F.** Pileus covering. Bars = 10 µm.

Leucocoprinus brebissoni (Godey) Locquin in Bulletin mensuel de la Société Linnéenne de Lyon 12: 41 (1943)

Lepiota brebissoni Godey in Gillet, Hyménomycètes: 64 (1874)

Leucocoprinus otsuensis Hongo in Journal of Japanese Botany 28: 70 (1953)

Fig. 31. A-F; Pl. 30.

Basidiomata small to somewhat medium-sized. **Pileus** 12-30 mm diam., subglobose when young, becoming campanulate to broadly convex and finally applanate, with an indistinct umbo; surface yellowish white (1A2, 3A2) with minute, brown (6E7, 7E7) squamules which are sparse towards the margin and concentrated towards the disc, pruinose at the disc, distinctly sulcate-striate towards the margin; incurved when young, becoming straight, crenate. **Lamellae** free, yellowish white (1A2, 3A2), crowded, up to 2 mm wide, with lamellulae in 1-3 tiers; edge fimbriate under a lens, concolorous with the sides. **Stipe** 40-70 × 1-3 mm (up to 5 mm at the base), central, terete, almost equal, expanding towards the base, initially fistulose, becoming hollow; surface concolorous with the pileus, fibrillose; base arising from a white mycelium. **Annulus** central to inferior, membranous. **Context** less than 1 mm thick, whitish to yellowish white (3A2). **Odour** not distinctive. **Spore-print** white.

Spores 9-13 × 6-9 (11 ± 0.68 × 7.8 ± 0.6) µm, Q = 1.25-1.6, Qm = 1.4, ellipsoid or broadly ellipsoid, rarely ovoid, with a germ-pore up to 1 µm broad and with a hyaline cap, hyaline, with refractive guttules, thick-walled

(up to 1.5 µm), smooth, dextrinoid, metachromatic in cresyl blue, cyanophilic in cotton blue. **Basidia** 20-32 × 10-12 µm, clavate, bearing 4 sterigmata up to 4 µm long. **Lamella-edge** sterile. **Cheilocystidia** 12-65 × 10-20 µm, cylindrical, clavate, inflated clavate or utriform, hyaline, thin-walled. **Pleurocystidia** absent. **Lamellar trama** subregular; hyphae 4-25 µm wide, inflated, hyaline, thin-walled, septate, inamyloid. **Subhymenium** cellular. **Pseudoparaphyses** abundant and well-developed. **Pileal trama** interwoven; hyphae 5-17 µm wide, inflated, thin-walled, hyaline, inamyloid. **Pileal covering** a cutis disrupted by patches of ascending chains of ellipsoid, cylindric, subglobose or globose elements, 12-45 × 5-10 µm/ 15-25 µm diam., thin- to slightly thick-walled, pale brown to brown, forming an almost irregular epithelium at the disc. **Stipe covering** basically a cutis of 3-13 µm wide, hyaline and thin-walled hyphae disrupted by ascending or erect patches of hyphae which are slightly agglutinated and terminated by cylindrical, 35-100 × 3-7 µm elements with obtuse tips. All hypahe lack clamp-connections.

Habitat: On soil, among decaying leaf litter, solitary and scattered.

Known Distribution: The Lesser Antilles, Brazil, Europe, India, Japan

Collections examined — Malappuram District, Calicut University Campus: 7 October 2004, AK126; 5 November 2004, AK171; 10 November 2004, AK171a; 10 November 2004, AK188; 3 July 2006, AK408.

The present collections fit in well with the descriptions of the species given by Smith (1981), Pegler (1983), Babos (1985), Migliozzi *et al.* (1989a), Vellinga (2001c) and Vrinda *et al.* (2003). Smith's description seems to be based on materials with larger and more robust basidiomata than that of the present collections. A colour photograph and the accompanying species description given by Migliozzi *et al.* (1989a) depict basidiomata with brownish squamules on a pale yellow pileal background whereas according to Vellinga (2001c) the squamules may be dark grey-brown, grey-brown, dark brown to almost blackish on a cream coloured or whitish background. Earlier report on the species from Kerala (Vrinda *et al.* 2003) records the pileal surface as 'teak brown (6F5), dark brown (7F8) at the disc' and with dark brown squamules on a dull white background. But pileal squamules of the present collections are much lighter and devoid of any grey to blackish squamules. This is a regularly fruiting species in the Malappuram District of Kerala, striking by its sharply contrasting squamules, on a whitish background.

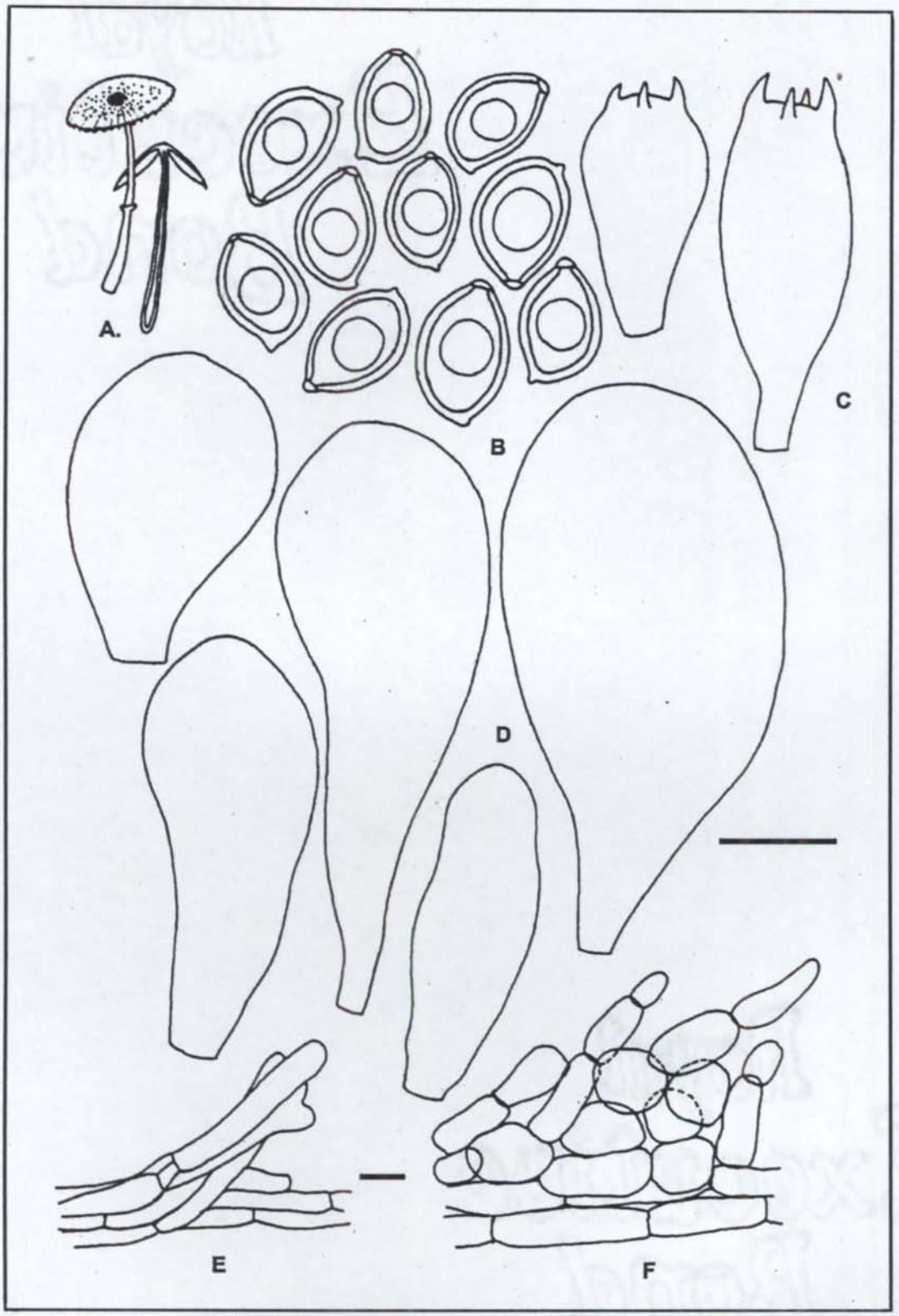


Figure 31. *Leucocoprinus brebissoni* **A.** Habit x 1 **B.** Spores **C.** Basidia **D.** Cheilocystidia **E.** Stipe covering **F.** Pileus covering. Bars = 10 µm.

Plate 29. *Leucocoprinus* species 1 **A.** x 2.5, **B.** x 1

Plate 30. *Leucocoprinus brebissoni* x 3

Leucocoprinus venezuelanus Dennis in Kew Bulletin 15: 109 (1961)

Fig. 32. A-F; Pl. 31.

Basidiomata small to somewhat medium-sized. **Pileus** 20-40 mm diam., campanulate when young, becoming convex to broadly convex, with an obtuse or rather indistinct umbo; surface white to pinkish white (10A2), with scattered, cinnamon (6D6), rust brown (6E8) or reddish brown (8E8) appressed squamules which are sparse towards the margin and concentrated towards the disc, distinctly sulcate-striate towards the margin, fibrillose; margin initially incurved, later straight, crenate. **Lamellae** free, white, moderately crowded, up to 2.5 mm wide, with lamellulae in 2-3 tiers; edge finely fimbriate under a lens, concolorous with the sides. **Stipe** 35-45 × 3-5 mm (up to 7 mm at the base), central, terete, almost equal for the most part but expanding towards the base and becoming bulbous, initially fistulose, becoming hollow; surface whitish to dull white, fibrillose; base attached to white mycelial cords. **Annulus** inferior or almost central, membranous, fixed. **Context** less than 1 mm thick, whitish. **Odour** not distinctive. **Spore-print** not obtained.

Spores 6-10 × 4.5-6.5 (8.8 ± 0.9 × 5.7 ± 0.44) µm, Q = 1.3-1.8, Qm = 1.5, mostly amygdaliform, some ellipsoid or ovoid, with a germ-pore covered by a hyaline cap, hyaline, with refractive guttules, thick-walled, smooth, dextrinoid, metachromatic in cresyl blue, cyanophilic in cotton blue. **Basidia** 14-20 × 7-10 µm, clavate, bearing 4 sterigmata up to 4 µm long. **Lamella-**

edge sterile. **Cheilocystidia** 12-50 × 10-20 µm, clavate, inflated clavate or utriform, hyaline, thin-walled. **Pleurocystidia** absent. **Lamellar trama** subregular; hyphae 4-19.5 µm wide, inflated, hyaline, thin-walled, septate, inamyloid. **Subhymenium** cellular. **Pseudoparaphyses** abundant and well-developed. **Pileal trama** interwoven; hyphae 5-17 µm wide, inflated, thin-walled, hyaline, inamyloid. **Pileal covering** a cutis disrupted by patches of ascending ellipsoid, cylindric or subglobose elements 15-60 × 5-18 µm, thin- to slightly thick-walled, pale brown to brown. **Stipe covering** a cutis of 2-10 µm wide, hyaline and thin-walled hyphae disrupted by patches of ascending or erect hyphae terminated by cylindrical, 20-60 × 4-8 µm elements with obtuse tips. All hypahe devoid of clamp-connections.

Habitat: On decaying coconut husk, solitary and scattered.

Known Distribution: AFRICA, the Lesser Antilles, Galapogos, India, Venezuela

Collections examined — Wayanad District, Pookode: 26 May 2004, AK40; 27 June 2005, AK40a; Calicut District, Thamarassery: 26 November 2006, AK461.

Except for the clavate to inflated-clavate or utriform cheilocystidia, characters of the present collections agree well with the original description of the species from Venezuela (Dennis 1961). The collections also agree

with the descriptions provided for materials from the Lesser Antilles (Pegler 1983) and India (Vrinda *et al.* 2003). The species closely resemble *Leucocoprinus brebissoni* with similar basidiomata but differs in having smaller spores. This is a species rarely encountered in Kerala. It has already been reported from Kerala (Vrinda *et al.* 2003).

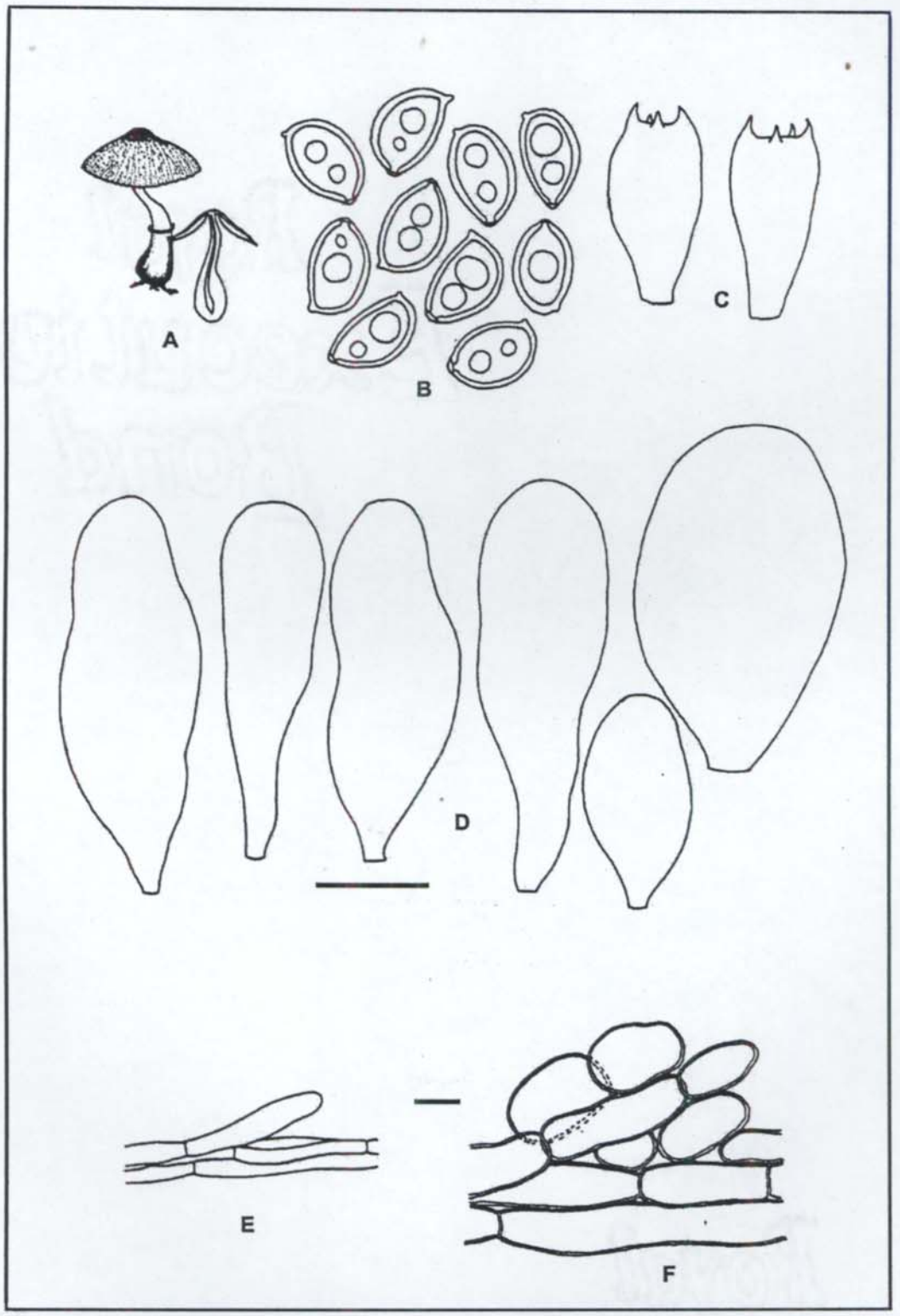


Figure 32. *Leucocoprinus venezuelanus* **A.** Habit x 1 **B.** Spores **C.** Basidia **D.** Chellocystidia **E.** Stipe covering **F.** Pileus covering. Bars = 10 µm.

***Leucocoprinus* species 2**

Fig. 33. A-F; Pl. 32.

Basidiomata small and somewhat fragile. **Pileus** 10-41 mm diam., convex, becoming broadly convex to applanate, umbonate at the disc; surface whitish with grey (1F1), appressed squamules which are concentrated more towards the disc and sparser towards the margin, pruinose at the disc, distinctly striate towards margin; margin initially incurved, later straight, entire to eroded. **Lamellae** free, whitish, crowded, up to 2 mm wide, with lamellulae in 1-2 tiers; edge fimbriate under a lens, concolorous with the sides. **Stipe** 45-60 × 1-2 mm, (up to 5 mm at the base), central, terete, almost equal with a dilated base, fistulose, becoming hollow; surface whitish, changing to greyish brown (8E3, 9E3) with age or on bruising, fibrillose-villose to rather tomentose; base arising from white mycelium. **Annulus** inferior, central or superior, membranous, ascending, fixed. **Context** up to 1 mm thick, whitish. **Odour** not distinctive. **Spore-print** white.

Spores 9-12 × 6-7 (10.7 ± 1.09 × 6.8 ± 0.54) µm, Q = 1.4-2, Qm = 1.6, ovo-ellipsoid to subamygdaliform, with a truncate germ-pore covered with a hyaline cap, hyaline, with refractive guttules, thick-walled (up to 2 µm), smooth, dextrinoid, metachromatic in cresyl blue, cyanophilic in cresyl blue. **Basidia** 16-24 × 10-11 µm, short clavate, hyaline, with guttulate contents, bearing 4 sterigmata up to 4 µm long. Lamella-edge sterile.

Cheilocystidia crowded, 26-66 × 11-21 µm, clavate, broadly clavate, lageniform, fusiform or utriform, mostly subcapitate or with flexuose apical prolongations (up to 20 µm long), hyaline, thin-walled. **Pleurocystidia** absent. **Lamellar trama** subregular; hyphae 2-6 µm wide, inflated up to 15 µm, branched, hyaline, thin-walled, inamyloid. **Subhymenium** cellular. **Pseudoparaphyses** abundant and well-developed. **Pileal trama** interwoven; composed of 5-20 µm wide, hyaline, thin-walled, inflated hyphae, inamyloid. **Pileal covering** a cutis disrupted by patches of ascending or erect loosely attached terminal elements and entirely trichodermial at the disc; hyphae 3-10 µm wide, thin-walled, hyaline or with grey to dark grey plasmatic and encrusting pigments; terminal elements 28-100 × 4-10 µm, cylindrical with acuminate to obtuse tips or with short or long flexuose apical extensions, thin- to slightly thick-walled. **Stipe covering** a cutis disrupted by ascending or erect slightly inflated, cylindric to flexuose terminal elements or side branches of repent hyphae; terminal elements, 24-92 × 7-10 µm; hyphae 3-17 µm wide, thin-walled, hyaline or with grey to dark grey plasmatic pigment. All hypahe devoid of clamp-connections.

Habitat: On soil, among decaying leaf litter, solitary or scattered.

Known Distribution: Only from the type locality.

Collections examined — Malappuram District, Calicut University Campus: 11 April 2005, AK211; 12 April 2005, AK211a; 13 April 2005, AK213; 3 June 2005, AK231.

This fragile coprinoid species is distinct with large truncate spores; short, clavate basidia; clavate, lageniform, fusiform or utriform cheilocystidia with apical excrescences; and cylindrical pileal elements mostly with abruptly constricted apices. This species highly resemble *Leucocoprinus ianthinus* (Cooke) Locquin (= *L. lilacinogranulosus* (Hennings) Locquin, in general appearance. However, microscopically the present collection could be distinguished from *L. ianthinus* by the cheilocystidia with apical prolongations and a trichodermial pileal disc entirely made up of cylindric pileal elements that reach up to 100 µm in length.

196.19

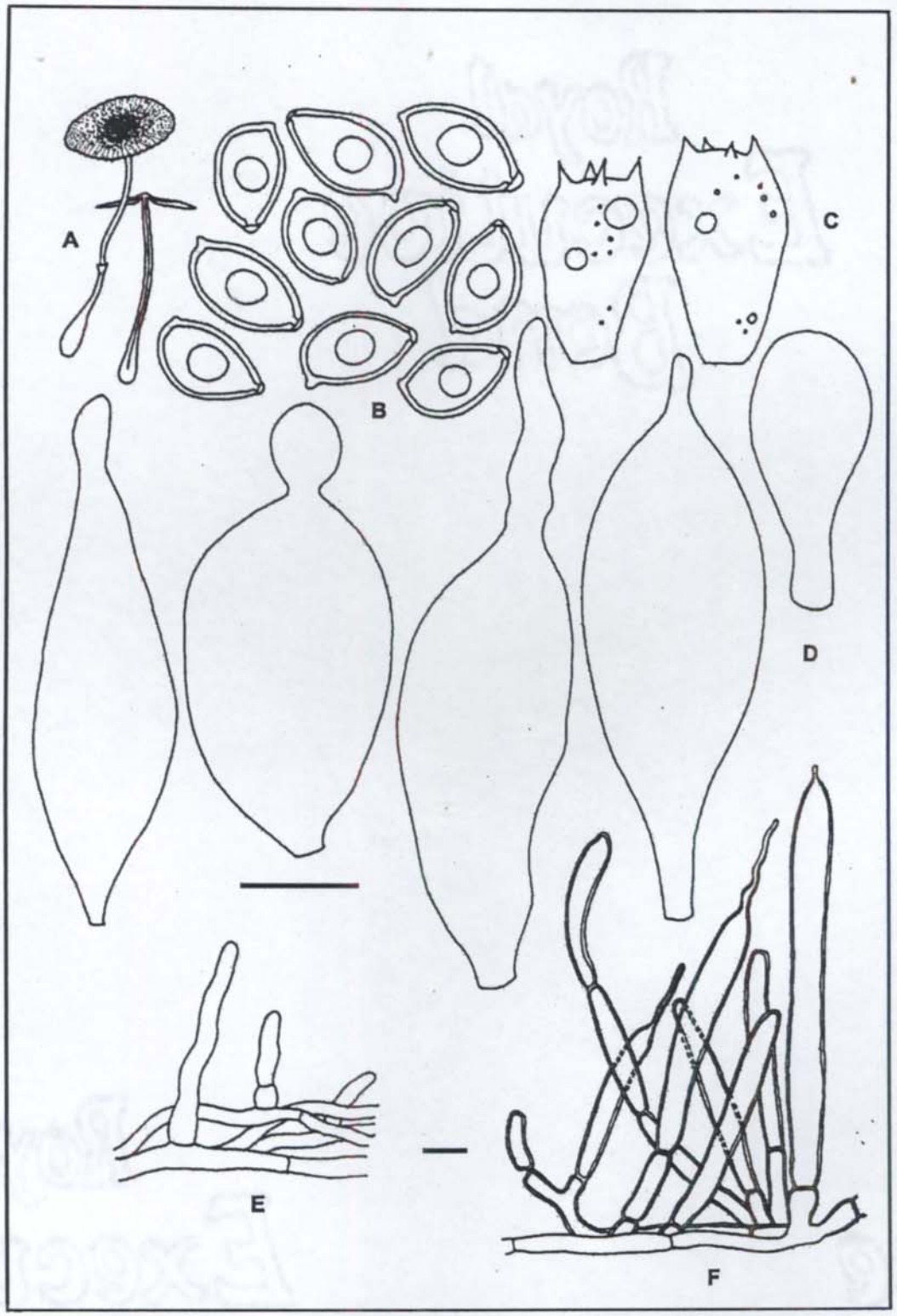


Figure33. *Leucocoprinus* species 2 **A.** Habit x 1 **B.** Spores **C.** Basidia **D.** Cheilocystidia **E.** Stipe covering **F.** Pileus covering. Bars = 10 µm.

Plate 31. *Leucocoprinus venezuelanus* x 2.5

Plate 32. *Leucocoprinus* species 2 x 3

***Leucocoprinus* species 3**

Fig. 34. A-F; Pl. 33.

Basidiomata small. **Pileus** 13-16 mm diam., subglobose to convex, becoming broadly convex, with a rather indistinct umbo; surface white with scattered, minute, dark brown (8F8) to dark grey (8F1), fibrillose squamules that are more concentrated recurved at the disc and sparser towards margin, distinctly sulcate-striate towards margin; margin initially incurved, later straight, entire. **Lamellae** free, whitish, turning yellowish white (3A2) to brown (6E6) with age and on drying, crowded, up to 2 mm wide, with lamellulae in 3-4 tiers; edge finely fimbriate under a lens, concolorous with the sides. **Stipe** 20-22 × 3-5 mm, central, terete, expanding towards base, fistulose; surface whitish, turning brown (6E5, 6E6) on bruising, fibrillose; base arising from a whitish mycelium. **Annulus** superior, membranous, ascending, with a rim covered with dark brown (8F8) fibrillose scales. **Context** up to 1 mm thick, whitish, turning brown (6E6) on exposure. **Odour** not distinctive. **Spore-print** not obtained.

Spores 7-10 (11) × 5-6 (7) (8 ± 1 × 5.9 ± 0.54) µm, Q = 1.2-1.6, Qm = 1.4, ovoid, ovo-ellipsoid, or ellipsoid, with a rather inconspicuous germ-pore (up to 1 µm in some), hyaline, with refractive guttules, thick-walled (up to 1.5 µm), smooth, dextrinoid, metachromatic in cresyl blue, cyanophilic in cotton blue. **Basidia** 18-27 × 9-12 µm, clavate, hyaline, with guttulate contents, bearing 4 sterigmata up to 3 µm long. **Cheilocystidia** crowded, 26-49 × 7-19

µm, cylindrico-clavate, clavate, inflated clavate, or utriform, many with a slightly mucronate apex (up to 3 µm long), hyaline, thin-walled. **Pleurocystidia** absent. **Lamellar trama** subregular; hyphae 2-5 µm wide, inflated up to 16 µm, hyaline, thin-walled, inamyloid. **Subhymenium** cellular. **Pseudoparaphyses** well-developed. **Pileal trama** interwoven; hyphae 3-17 µm wide, hyaline, thin- to slightly thick-walled, slightly inflated, inamyloid. **Pileal covering** a cutis composed of filamentous, 2-15 µm wide, slightly agglutinated, hyaline to pale greyish, thick-walled (up to 1 µm) hyphae, which becomes highly disrupted and irregular at the disc and at the scales, with ascending or erect terminal elements; terminal elements 17-69 × 5-17 µm, mostly clavate or lageniform, rarely cylindrico-clavate, or utriform, thick-walled (up to 1 µm), with dark greyish brown plasmatic, membrane and encrusting pigments. **Stipe covering** a cutis of 2-12 µm wide, thin-walled, hyaline or pale yellow to brownish, slightly agglutinated hyphae with cylindrical end-cells. Clamp-connections absent.

Habitat: On organic manure rich soil, solitary.

Known Distribution: Only from the type locality.

Collections examined — Thiruvananthapuram District, Palode: 20 July 2005, AK367; 20 July 2005, TBGT 9140.

This is a striking species of the genus *Leucocoprinus* with ellipsoid to ovo-ellipsoid spores having an inconspicuous germ-pore, cheilocystidia with a rarely mucronate apex and thick-walled pileal elements with plasmatic, membrane and encrusting pigments. This character combination indicates affiliation with the '*Leucocoprinus badhamii* complex' that according to Reid (1990) is characterized by species with a rubescent flesh that become green in ammonia fumes. Remarkably, a colour reaction on exposure to ammonia was found to be absent in the present species although the context turned brown (6E5, 6E6) on bruising. *Leucocoprinus croceovelutinus* Bon & Boiffard seems to be the only exceptional species of the 'badhamii complex' that shows a negative ammonia reaction (Babos 1979; Reid 1990). But that species is of moderate size (30-40 mm diam.) with a non-striate pileal margin. It reddens on bruising and has spores with a distinct papillate apex without a germ-pore and cheilocystidia with prominent apical prolongation. The negative reaction with ammonia and the characteristically small size of basidiomata of the present collections keeps it distinct from all other members of the group.

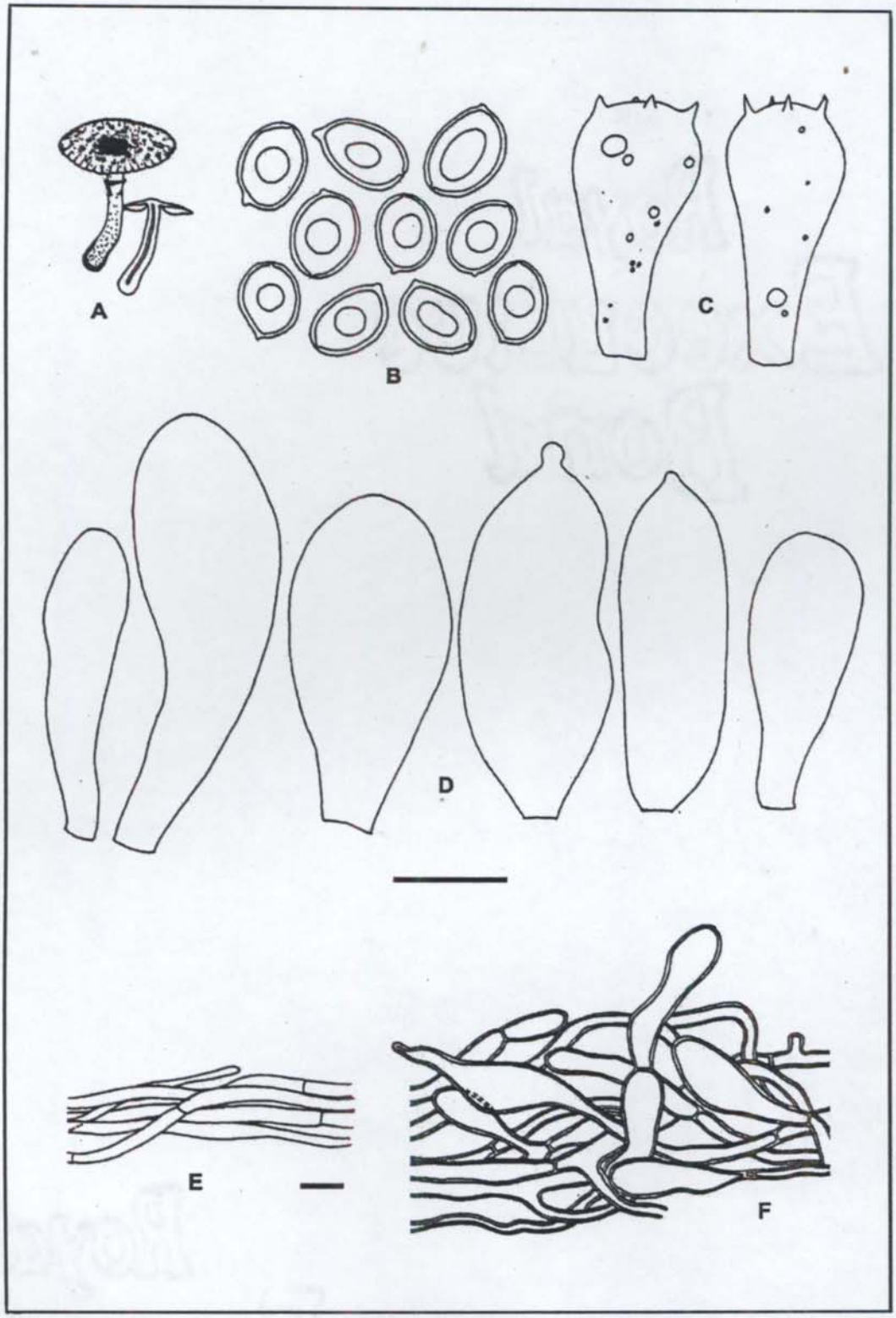


Figure 34. *Leucocoprinus* species 3 **A.** Habit x 1 **B.** Spores **C.** Basidia **D.** Cheilocystidia **E.** Stipe covering **F.** Pileus covering. Bars = 10 µm.

***Leucocoprinus* species 4**

Fig. 35. A-F; Pl. 34.

Basidiomata small to somewhat medium-sized. **Pileus** 27-51 mm diam., initially convex, becoming broadly convex to applanate, umbonate at the disc; surface whitish with scattered, minute, dark grey (1F1) to blackish, squamules that are almost granular and more concentrated towards the centre and sparser towards the margin, distinctly striate towards margin; margin initially incurved, later straight, entire or slightly eroded in some specimen. **Lamellae** free, whitish, crowded, up to 2.5 mm wide, with lamellulae in 2-5 tiers; edge fimbriate under a lens, concolorous with the sides. **Stipe** 50-80 × 3-5 mm, (up to 5 mm at the base), central, terete, almost equal, slightly expanding towards base, fistulose, finally becoming hollow; surface whitish, turning brown (6E5, 6E6) on touch, on bruising or when cut, fibrillose; base arising from whitish mycelium. **Annulus** superior, membranous, movable, evanescent. **Context** up to 1 mm thick, whitish, gradually turning brown (6E5) on exposure. **Odour** not distinctive. **Spore-print** not obtained.

Spores 8.5-12.5 × 6-8 (10.4 ± 1.04 × 7 ± 0.54) µm, Q = 1.3-1.7, Qm = 1.5, amygdaliform, with a germ-pore covered by a hyaline pore-cap, hyaline, with refractive guttules, thick-walled (up to 1 µm), smooth, dextrinoid, distinctly metachromatic in cresyl blue, cyanophilous in cotton blue. **Basidia** 19-22 × 10-11 µm, clavate, hyaline, with guttulate contents, bearing 2-4

sterigmata up to 7 µm long. **Cheilocystidia** crowded, 41-66 × 10-25 µm, clavate, versiform: inflated clavate, narrowly lageniform, or utriform, mostly with cylindrical or flexuose apical prolongations up to 27 µm long, hyaline, thin-walled. **Pleurocystidia** absent. **Lamellar trama** subregular; hyphae 3-15 µm wide, inflated up to 30 µm, hyaline, thin-walled, inamyloid. **Subhymenium** cellular. **Pseudoparaphyses** well-developed and prominent. **Pileal trama** interwoven; composed of 5-25 µm wide, hyaline, thin-walled, inflated, inamyloid hyphae. **Pileal covering** a disrupted cutis composed of 3-25 µm wide, slightly inflated, thin- to slightly thick-walled, grey to dark grey pigmented hyphae, with ascending or erect trichodermial patches of fusoid or cylindrical, thin- to slightly thick-walled terminal elements, 43-190 × 4-10 µm, with obtuse tips. **Stipe covering** a cutis of 4-11 µm wide, thin-walled, hyaline hyphae, disrupted by bundles of ascending or erect terminal elements; terminal elements; 30-57 × 3-7 µm, cylindrical, with hyaline to pale grey plasmatic pigment. All hypahe lack clamp-connections.

Habitat: On soil, solitary or scattered.

Known Distribution: Only from the type locality.

Collections examined — Idukki District, Madupetty: 10 June 2006, AK393.

The distinctive characters of this species are basidiomata that turns brown on bruising but not reacting by colour change with ammonia, large

spores with a broad germ-pore covered by a hyaline cap, cheilocystidia with mucronate apex, and a trichodermial pileal disc made up entirely of fusoid or cylindric terminal elements that may reach up to 190 µm in length. Previously descibed species that perfectly agree with the present description could not be found in the available literature in spite of a thorough search. *Leucocoprinus brebissonii* (Godey) Locquin, earlier reported as occurring in the Western Ghats of Kerala (Vrinda *et al.* 2003), seems to be very close. But the present species doesnot agree with the descriptions of *L. brebissonii* (Candusso & Lanzoni 1990; Bon 1996; Vellinga 2001c; Vrinda *et al.* 2003) on account of the brownish colour change of basidiomata in the former, and in the morphology and dimensions of the terminal cells of pileal covering, where they are usually described as 'cylindrical and short to ellipsoid-clavate to globose elements, in chains or disorderly arrangements' (Vellinga 2001c) in the latter. Vrinda *et al.* (2003) mentions the pileal covering at the pileal disc of *L. brebissonii* as 'hymeniform' with 'clavate to ovoid, detersile elements'. A comparison with the colour photograph of *L. brebissonii* given in Migliozzi *et al.* (1989a: 27) also confirms distinction between the two.

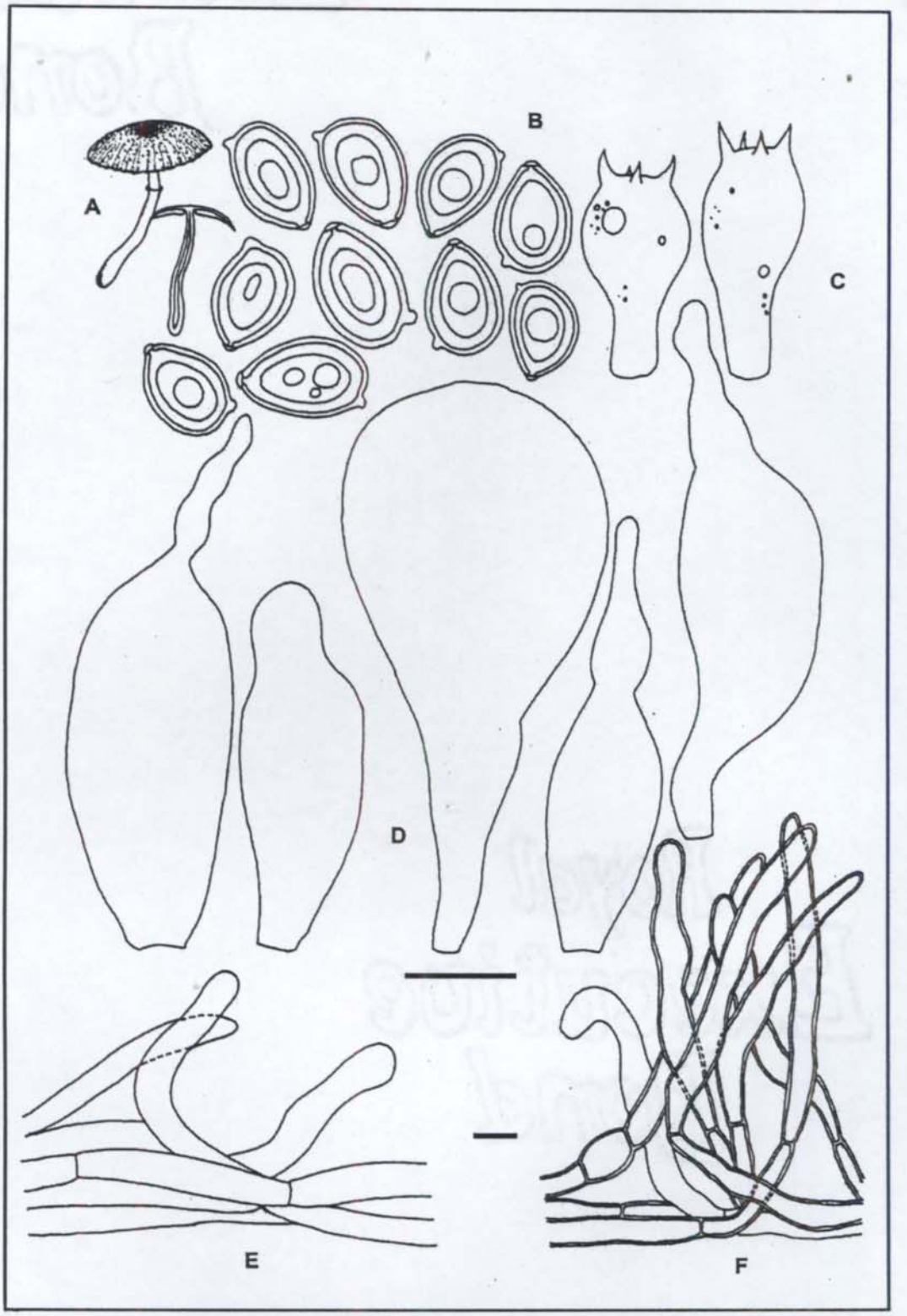


Figure 35. *Leucocoprinus* species 4 **A.** Habit x 1 **B.** Spores **C.** Basidia **D.** Cheilocystidia **E.** Stipe covering **F.** Pileus covering. Bars = 10 µm.

Plate 33. *Leucocoprinus* species 3 x 4

Plate 34. *Leucocoprinus* species 4 x 2.5

Leucocoprinus cretaceus (Bulliard) Locquin in Bulletin mensuel de la Société Linnéenne de Lyon 14: 93 (1945)

Agaricus cretaceus Bulliard in Herbier de la France: plate 374 (1788)

Agaricus cretaceus Bulliard in Systema mycologicum, Index generalis: 14 (1832), non *Agaricus cretaceus* Persoon (1801), nec *Agaricus cretaceus* Persoon: Fries (1821)

Lepiota cretacea (Bulliard) Quélet in Flore mycologique de la France et des pays limitrophes: 298 (1881)

- *Lepiota cretata* Locquin in Haller in Mitteilungen der Aargauischen naturforschenden Gesellschaft 23: 82 (1950) (not valid)

Leucocoprinus cretatus (Locquin) Moser in Die Blätter- und Bauchpilze, 1: 116 (1953) (not valid)

Leucocoprinus cretatus Locquin ex Lanzoni in Atti di XIX Comitato Scientifico Nazionale, Serina (Bergamo): 30-31 (1986)

Fig. 36. A-F; Pl. 35.

Basidiomata small to fairly large. **Pileus** 10-85 mm diam., ovoid when very young, becoming broadly convex to campanulate and finally applanate, with a broad umbo; surface white or yellowish white (2A2), greyish orange (4B4, 5B2, 5B3, 5B4) towards disc, furfuraceous, with floccose squamules scattered over the entire pileus, finely striate towards margin; margin initially incurved, later straight, entire. **Lamellae** free, white, crowded, up to 10 mm wide, with lamellulae in 3-7 tiers; edge finely fimbriate under a lens, concolorous with the sides. **Stipe** 20-130 × 2-10 mm (up to 14 mm wide at the base), central, terete, expanding towards base, solid when very young, becoming fistulose to hollow with age; surface white, becoming yellow (4A5, 4A6, AB6) on handling, densely fibrillose to granular or

floccose; base arising from white mycelium. **Annulus** superior, ascending, membranous, movable, fugacious. **Context** up to 6 mm thick, white. **Odour** not distinctive. **Spore-print** white.

Spores 6-12 × 5-7 (9.2 ± 1.4 × 6.25 ± 0.55) µm, Q = 1.2-2, Qm = 1.5, ovoid to oblong-ellipsoid, with a germ-pore covered with a lens-cap-like exudate, hyaline, with refractive guttules, thick-walled, smooth, dextrinoid, metachromatic in cresyl blue, cyanophilous in cotton blue. **Basidia** 16-23 × 9-12 µm, clavate, with guttulate contents, bearing 4 sterigmata up to 5 µm long. **Lamella-edge** sterile. **Cheilocystidia** 15-65 × 7-14 µm, lageniform, utriform or clavate, with a mucronate subcapitate or flexuose apex, hyaline, thin-walled. **Pleurocystidia** absent. **Lamellar trama** subregular; hyphae 4-20 µm wide, inflated, hyaline, thin-walled, inamyloid. **Subhymenium** cellular. **Pseudoparaphyses** well-developed. **Pileal trama** interwoven; hyphae 2-20 µm wide, inflated, hyaline, thin-walled, inamyloid. **Pileal covering** a highly disrupted cutis; hyphae 2-20 µm wide, thin-walled, hyaline; terminal elements 16-85 × 7-13 µm, short cylindrical or ellipsoid, rarely branched, ascending or erect, simple or in fascicles. **Stipe covering** a disrupted cutis of irregular, 2-25 µm wide, thin- to thick-walled, hyaline to light yellow filamentous hyphae with loose fascicles of erect cylindrical terminal elements, 21-92 × 2-19 µm, thin-walled, hyaline or pale yellow. All hypahe lack clamp-connections.

Habitat: On soil, decaying leaf litter, or decaying wood, solitary or scattered.

Known Distribution: AFRICA, EUROPE, Sri Lanka

Collections examined — Malappuram District, Calicut University Campus: 8 October 2003, AK3; 4 May 2004, AK19; 5 May 2004, AK21; 6 May 2004, AK21a; 29 June 2004, AK60; 19 July 2004, AK69; 8 July 2006, AK437.

Characters of the above materials match the description of the species from Sri Lanka, given by Pegler (1986) under the name *Leucocoprinus cepaestipes* (Sowerby) Patouillard. However, the name seems to have been misapplied to the taxon currently recognized as *L. cretaceus* (Bulliard) Locquin (see Vellinga 2001c; *L. cretatus* (Locquin) Moser according to Reid & Eicher 1993a), characterized by somewhat large basidiomata, with chalk-white (with yellowish white to grayish orange tinges at pileal disc), cottony or plush-like detersile floccose-squamulose covering on the pileus and stipe, spores often with a conspicuous hyaline cap over the germ-pore and with cylindrical, slightly branched elements of pileal covering. Remarkably, the description of collections from Kerala also agrees well with the description of *L. cretaceus* given by Vellinga (2001c), and therefore is treated here under that epithet.

Leucocoprinus cepaestipes in the present sense has a pileus with brownish centre and uplifted brownish squamules, stipe with a densely and finely pubescent surface, spores with germ-pore lacking a distinct hyaline cap and cylindrical to narrowly lageniform terminal elements on the pileus and stipe covering.

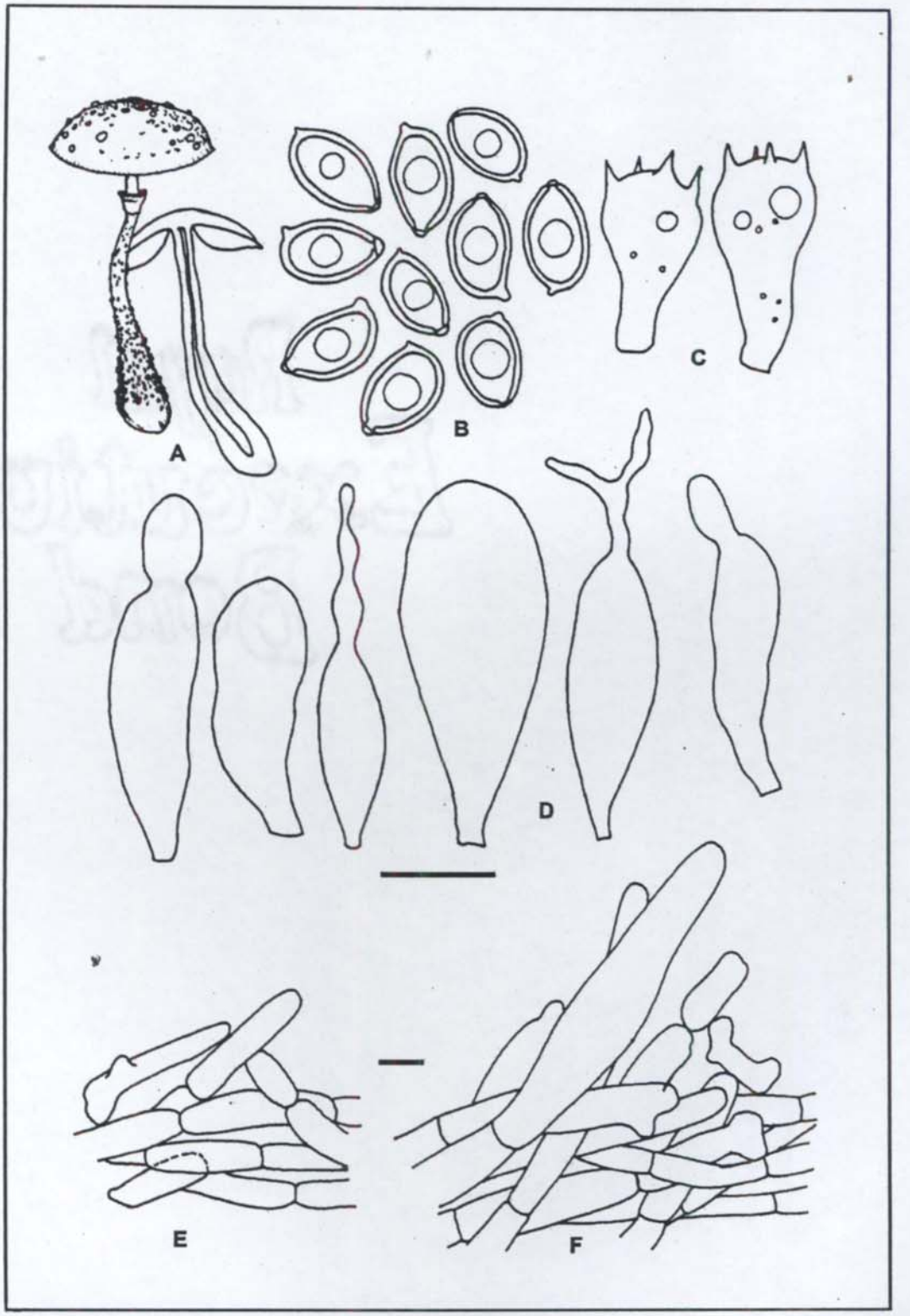


Figure 36. *Leucocoprinus cretaceus* **A.** Habit x 1 **B.** Spores **C.** Basidia **D.** Cheilocystidia **E.** Stipe covering **F.** Pileus covering. Bars = 10 µm.

Leucocoprinus birnbaumii (Corda) Singer in Sydowia, 15: 67 ('1961') (1962)

Agaricus birnbaumii Corda in Icones fungorum hucusque cognitorum 3: 48 (1839)

Agaricus flos-sulfuris Schnizlein in Sturm, Deutschlands Flora, 3: 1 (1851), plate 1.

Lepiota flos-sulphuris (Schnizlein) Mattirolo in Atti dell' Accademia nazionale dei Lincei. Memorie, series V 12: (566) 34 (1918)

Leucocoprinus flos-sulfuris (Schnizlein) Cejp in Ĉeská Mykologie 2: 78 (1948)

Lepiota cepaestipes variety *flos-sulphuris* (Schnizlein) Rick in Iheringia, Botânica 8: 314 (1961) (not valid)

- *Agaricus luteus* Bolton in A history of fungusses growing in Halifax 2: plate 50 (1788), non *Agaricus luteus* Hudson (1778), nec *Agaricus luteus* Hudson: Fries (1821)

Lepiota lutea (Bolton) Godfrin in Bulletin de la Société mycologique de France 13: 33 (1897)

Leucocoprinus luteus (Bolton) Locquin in Bulletin mensuel de la Société Linnéenne de Lyon 14: 93 (1945)

- *Lepiota aurea* Massee in Kew Bulletin, 1912: 189 (1912), non *Lepiota aurea* (Mattuschka: Fries) Gray (1821)

Lepiota pseudolicmophora Rea in British Basidiomycetes: 74 (1922)

- *Lepiota coprinoides* Beeli in Flore iconographique des champignons du Congo

Fig. 37. A-F; Pl. 36.

Basidiomata small to medium-sized. **Pileus** 25-65 mm diam., ovoid when very young, becoming campanulate, conico-campanulate or applanate, with an indistinct umbo; surface greyish yellow (3B4, 4C6) at the centre, light yellow (1A4, 1A5) to pastel yellow (2A4) towards margin,

furfuraceous, with appressed to somewhat recurved squamules concentrated more towards the disc, distinctly sulcate-striate towards margin; margin incurved, becoming straight, entire. **Lamellae** free, light yellow (1A4, 1A5) to pastel yellow (2A4), crowded, up to 10 mm wide, with lamellulae in 2-4 tiers; edge finely fimbriate under a lens, concolorous with the sides. **Stipe** 50-80 × 2-5 mm (up to 10 mm at the base), central, terete, expanding towards base, solid when young, becoming fistulose to hollow with age; surface concolorous with the pileus, fibrillose. **Annulus** superior, membranous, evanescent. **Context** less than 3 mm thick, light yellow (1A4, 1A5) to pastel yellow (2A4). **Odour** not distinctive. **Spore-print** white to yellowish white (1A2).

Spores 8-11.5 × 5-7 (9.8 ± 0.44 × 6.7 ± 0.48) µm, Q = 1.3-1.6, Qm = 1.5, ovoid to ellipsoid with a truncated base and a germ-pore up to 1 µm broad, covered with a lens-cap-like exudate, hyaline, with refractive guttules, thick-walled, smooth, dextrinoid, metachromatic in cresyl blue, cyanophilous in cotton blue. **Basidia** 20-22 × 7.5-9.5 µm, clavate, with guttulate contents, bearing 4 sterigmata up to 5 µm long. **Lamella-edge** sterile with abundant cheilocystidia. **Cheilocystidia** dimorphic, some lageniform and 30-70 × 11-18 µm, others inflated clavate and 16-25 × 9-18 µm, both types hyaline and thin-walled. **Pleurocystidia** absent. **Lamellar trama** subregular; hyphae 2-7 µm wide, hyaline to pale yellow, septate, thin-walled, inamyloid. **Subhymenium** cellular. **Pseudoparaphyses** abundant. **Pileal trama** interwoven; hyphae 4-20 µm wide, inflated, hyaline to pale

yellow, thin-walled, inamyloid. **Pileal covering** a disrupted cutis forming patches of trichodermium of loosely arranged chains of detersile, cylindric elements; elements 20-60 × 4-9 µm, thin-walled, hyaline or with a pale yellow plasmatic pigment, at times branched. **Stipe covering** a cutis; hyphae loosely arranged; elements 20-50 × 2-10 µm, thin-walled, hyaline or pale yellow. All hyphae without clamp-connections.

Habitat: Mostly on decaying wood, also on decaying coconut fibre, solitary and scattered in groups.

Known Distribution: AFRICA, ASIA, AUSTRALIA, EUROPE, NORTH AMERICA, SOUTH AMERICA

Collections examined — Calicut District, Puthiyangadi: 25 July 2004, AK82, 1 September 2004, AK82a; Wayanad District, Kalpetta: 26 May 2004, AK39; Malappuram District, Calicut University Campus: 2 June 2004, AK42.

This species, easily identified by its yellowish basidiomata, ovoid to ellipsoid spores with a germ-pore, and cylindrical elements of pileal covering, is one of the widely known and studied lepiotaceous fungi. Although it is cosmopolitan in distribution, this species is encountered in the temperate regions in green houses, botanic gardens and from around the soil in plant-pots growing tropical plants. The species has already been reported from Kerala by Vrinda *et al.* (2003).

208.A

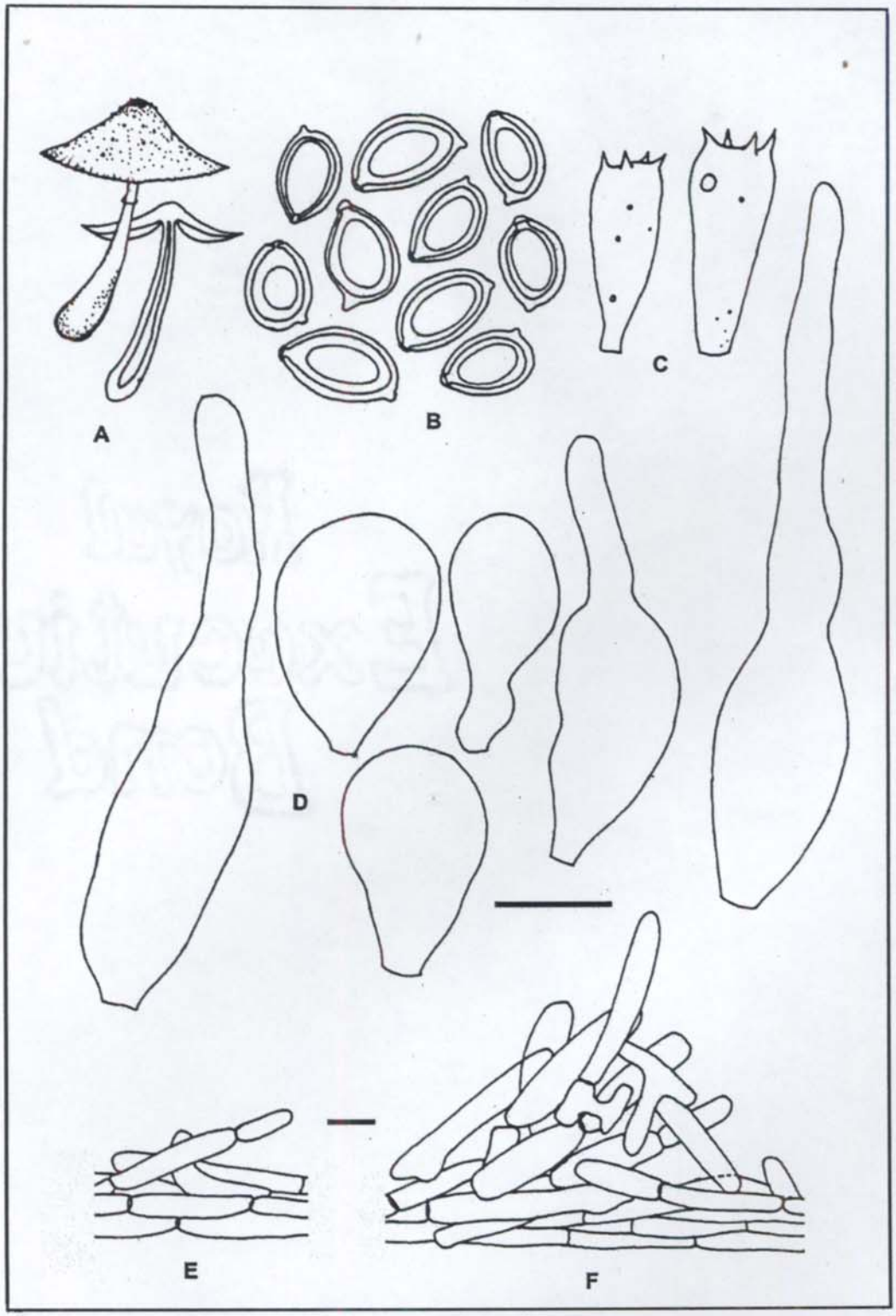


Figure37. *Leucocoprinus bimbaumii* **A.** Habit x 1 **B.** Spores **C.** Basidia **D.** Cheilocystidia **E.** Stipe covering **F.** Pileus covering. Bars = 10 µm.

Plate 35. *Leucocoprinus cretaceus* x 1.5

Plate 36. *Leucocoprinus birnbaumii* x 2

Leucocoprinus jubilaei (Josserand) Wasser in Novitates Systematicae Plantarum non Vascularium 2: 191 (1975) (1976)

Lepiota jubilaei Josserand in Bulletin mensuel de la Société Linnéenne de Lyon 43: 205 (1974)

Leucoagaricus jubilaei (Josserand) Bon in Documents Mycologiques 12: 44 (1982) (1983)

Fig. 38. A-F; Pl. 37.

Basidiomata small. **Pileus** 8-15 mm diam., initially convex becoming broadly convex to applanate with age, broadly umbonate at the disc; surface white with scattered dark grey (8F1) appressed fibrillose squamules concentrated more towards the centre, pruinose at the disc; margin initially incurved, becoming straight on maturity, crenate to somewhat appendiculate. **Lamellae** free, white, close to moderately crowded, thin, up to 2 mm wide, with lamellulae in 2 tiers; edge finely fimbriate under a lens, concolorous with the sides. **Stipe** 20-30 × 1-2 mm, central, terete, almost equal with a bulbous base, initially solid, becoming fistulose; surface white, turning rust brown (6E8) to reddish brown (8D8) on bruising, fibrillose-villose or rather tomentose with age; with white basal mycelium. **Annulus** superior, fibrillose, evanescent. **Context** less than 2 mm thick, white. **Odour** not distinctive. **Spore-print** white.

Spores 5-9 x 3-4.5 (6.8 ± 0.85 × 3.9 ± 0.37) µm, Q = 1.3-2.7, Qm = 1.81, amygdaliform with a slightly flattened apex, slightly thick-walled, smooth, dextrinoid, hyaline, with refractive guttules, metachromatic in cresyl blue, cyanophilous in cotton blue. **Basidia** 13-19 × 6-7 µm, clavate, bearing

4 sterigmata up to 4 µm long. **Lamella-edge** sterile. **Cheilocystidia** crowded, 12-65 × 4-15 µm, versiform, mostly clavate or lageniform, often with strangulated or flexuose apical prolongation up to 47 µm long and less than 7 µm wide, at times apically branched, thin-walled and hyaline. **Pleurocystidia** absent. **Lamellar trama** subregular; hyphae 2-10 µm wide, often inflated up to 22 µm, septate, hyaline, thin-walled, inamyloid. **Subhymenium** cellular. **Pseudoparaphyses** abundant. **Pileal trama** interwoven; made up of 3-25 µm wide, inflated, septate, thin-walled, hyaline and inamyloid hyphae. **Pileal covering** a disrupted cutis of filamentous hyphae, often with ascending or erect hyphae with cylindrico-clavate 19-104 × 5-12 µm, thin- to slightly thick-walled end-cells densely filled with a grey to dark grey plasmatic pigment. **Stipe covering** a cutis of loosely arranged filamentous hyphae disrupted by ascending or erect cylindrical terminal elements; terminal elements thin-walled, hyaline to pale grey pigmented. All hyphae devoid of clamp-connections.

Habitat: On soil, solitary or scattered.

Known Distribution: EUROPE, Turkey.

Collections examined — Malappuram District, Calicut University Campus: 15 October 2004, AK137; 26 October 2004, AK148; 26 October 2004 AK149; 1 November 2004, AK148a; 2 November 2004, AK163; 5 November 2004, AK172; 9 November 2004, AK172a; 10 November 2004, AK172b; 16

November 2004, AK202; Thiruvananthapuram District, Palode: 18 July 2005, AK368; 20 July 2005, AK371; 3 August 2006, AK424; 4 August 2006, AK427.

The present collections differ from the description of the species by Babos (1979) in showing a negative reaction with ammonia and by the absence of coloured pigments in cheilocystidia. It differs from the account given by Reid (1990) in the smaller size of basidiomata, and in the morphology of cheilocystidia. Ried (1990) in his comprehensive discussion on the species mentions that 'Ammonia gives a variable reaction from intense green to a rather feeble grey-green to absolutely no reaction'. This observation supports the negative chemical response of the Kerala collections. Materials from Hungary studied by Babos often possessed cheilocystidia with versiform appendages that were up to 54 µm long although she records the lack of apical appendages in Josserand's material and original descriptions. The developmental stage of the fruit bodies may explain the presence/absence of such outgrowths as mentioned by Babos (1979). Except for these deviating characters, the present collections are in agreement with the characteristics of the particular species.

This is a rather common *Leucocoprinus* species found throughout the State of Kerala.

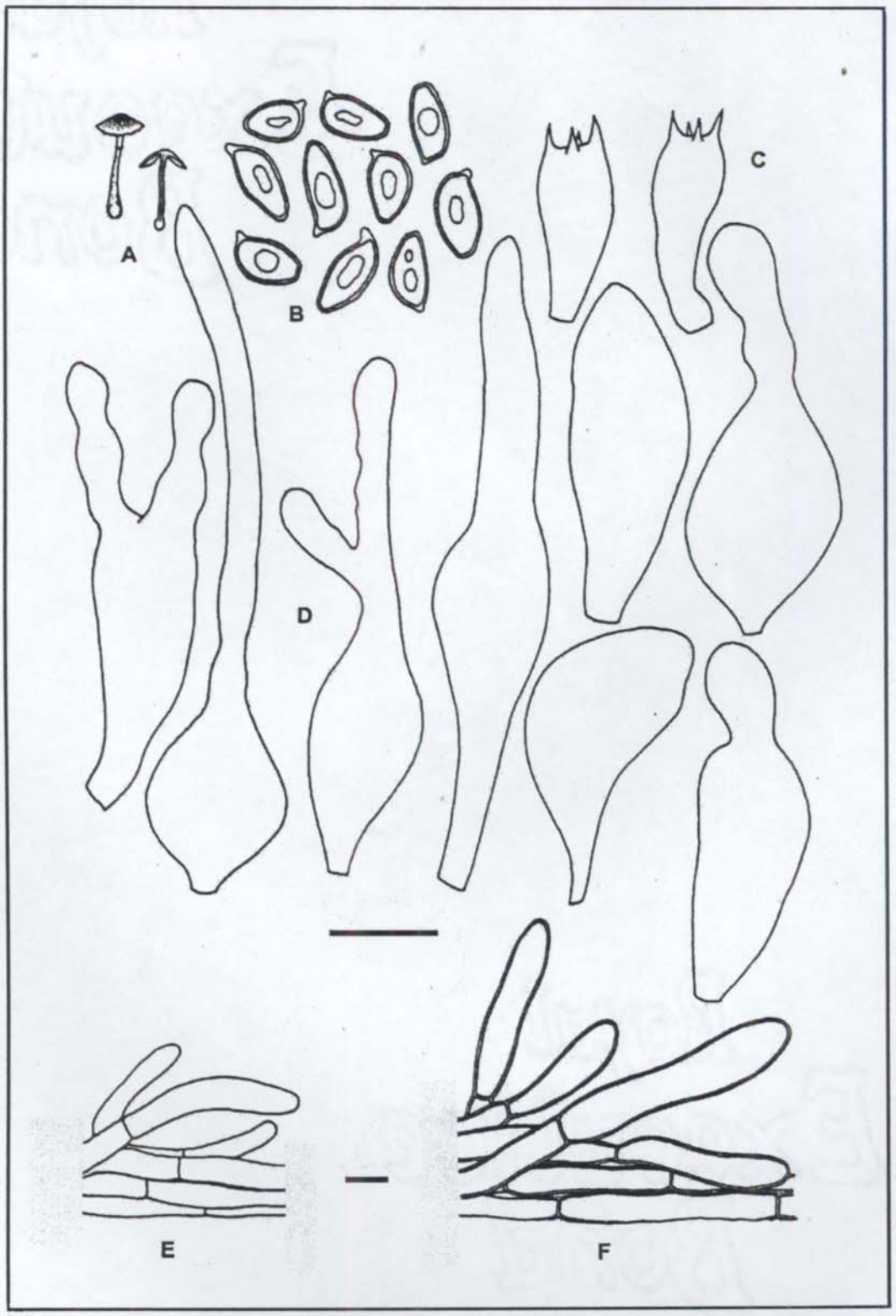


Figure 38. *Leucocoprinus jubilaei* **A.** Habit x 1 **B.** Spores **C.** Basidia **D.** Cheilocystidia **E.** Stipe covering **F.** Pileus covering. Bars = 10 µm.

Leucocoprinus submontagnei Heinemann in Bulletin de Jardin botanique national de Belgique 47: 84 (1977)

> *Lepiota montagnei* variety *congolensis* Beeli in Flore iconographique des champignons du Congo 2: 36 (1936)

Fig. 39. A-F; Pl. 38.

Basidiomata small, fragile. **Pileus** 10-20 mm diam., convex when young, becoming broadly convex to applanate, with a more or less indistinct umbo; surface whitish to yellowish white (2A2) with scattered granular or bran-like, yellowish white (3A2, 4A2), pale yellow (4A3), light yellow (4A4) or yellowish brown (5D6) squamules which are concentrated more towards disc and sparser towards the margin, fibrillose, distinctly sulcate-striate towards the margin; margin initially incurved, later straight, upturned with age, entire or eroded. **Lamellae** free, whitish to yellowish white (2A2), moderately crowded to crowded, up to 2 mm wide, with lamellulae in 1-3 tiers; edge finely fimbriate under a lens, concolorous with the sides. **Stipe** 28-41 × 1-2 mm, central, terete, almost equal, expanded towards the base, hollow; surface concolorous with the pileus, turning brown (7E3) with age or on handling, fibrillose-villose to rather velutinous; base arising from white mycelial cords. **Annulus** central, membranous, persistent. **Context** less than 1 mm thick, white to yellowish white (2A2). **Odour** not distinctive. **Spore-print** yellowish white (2A2).

Spores 5-10.5 × 3.5-6 (7.4 ± 0.93 × 4.9 ± 0.26) µm, Q = 1.4-2.1, Qm = 1.5, ovoid, ellipsoid or broadly ellipsoid, with an indistinct germ-pore,

hyaline, with refractive guttules, thick-walled, smooth, dextrinoid, metachromatic in cresyl blue, cyanophilous in cotton blue. **Basidia** 12-19 × 8-10 µm, clavate or rarely broadly clavate, with guttulate contents, bearing 4 sterigmata up to 3.5 µm long. **Lamella-edge** sterile. **Cheilocystidia** 12-37 × 6-18 µm, collapsing on drying, clavate, inflated clavate, utriform or obovoid, hyaline, thin-walled. **Pleurocystidia** absent. **Lamellar trama** subregular; hyphae 4-15 µm wide, inflated, hyaline, thin-walled, septate, inamyloid. **Subhymenium** cellular. **Pseudoparaphyses** abundant and well-developed. **Pileal trama** interwoven; hyphae 3-15 µm wide, hyaline, thin-walled, septate, inamyloid. **Pileal covering** a cutis disrupted by irregular chains of thin- to slightly thick-walled isodiammetric or ovoid to ellipsoid, 12-27 × 7-15 µm large cells often terminated by cylindric 20-51 × 5-9 µm large elements having a subcapitate apex and with a greyish brown plasmatic pigment; almost epithelium-like at the disc. **Stipe covering** a cutis disrupted by patches of ascending cylindrical to clavate terminal elements, 14-61 × 4-7 µm, thin- to slightly thick-walled, hyaline to pale grey and mostly having subcapitate apex, borne on loose chains of ovoid or cylindrical cells. All hypahe lack clamp-connections.

Habitat: On soil and decaying leaf litter, solitary or scattered.

Known Distribution: AFRICA, Colombia, Mexico

Collections examined — Calicut District, Puthiyangadi: 29 October 2003, AK9; 12 November 2003, AK9a; 9 May 2004, AK23; 19 May 2004, AK23a;

21 May 2004, AK23b; Malappuram District, Calicut University Campus: 24 May 2004, AK31; 24 May 2004, AK32; 3 June 2004, AK43; 9 November 2004, AK179; 10 November 2004, AK179a; 10 November 2004, AK189; 28 June 2005, AK320.

This fragile species is characterized by a whitish to yellowish white pileus that is distinctly sulcate-striate towards the margin; ovoid, ellipsoid or broadly ellipsoid spores with an indistinct germ-pore; and a pileal covering with cylindric elements projecting from chains of more or less ovoid to ellipsoid cells. The description of the present collections agrees with the diagnostic characters of the species from Africa (Heinemann 1977b; Pegler 1977) except for its slightly larger spores. *Leucocoprinus lanzonii* Bon, Migliozzi & Brunori closely resembles this species in general appearance and in most microscopic features, but differs in having slightly larger basidiomata and smaller spores. Other related species like *L. medioflavus* (Boudier) Bon and *L. denudatus* (Rabenhorst) Singer could also be distinguished based chiefly on size of basidiome and smaller spore dimensions. *Leucocoprinus denudatus*, although have subglobose spores without a germ-pore, differs in the arrangement and shapes of its pileal elements. *Leucocoprinus truncatus* (Pearson) Reid & Eicker resembles *L. submontagnei* in general appearance and in almost identical cuticular structure, but could be kept apart due to the presence of a thick annulus with brownish rim, and larger amygdaliform spores with apical germ-pore.

This is a wide-spread species in Kerala.

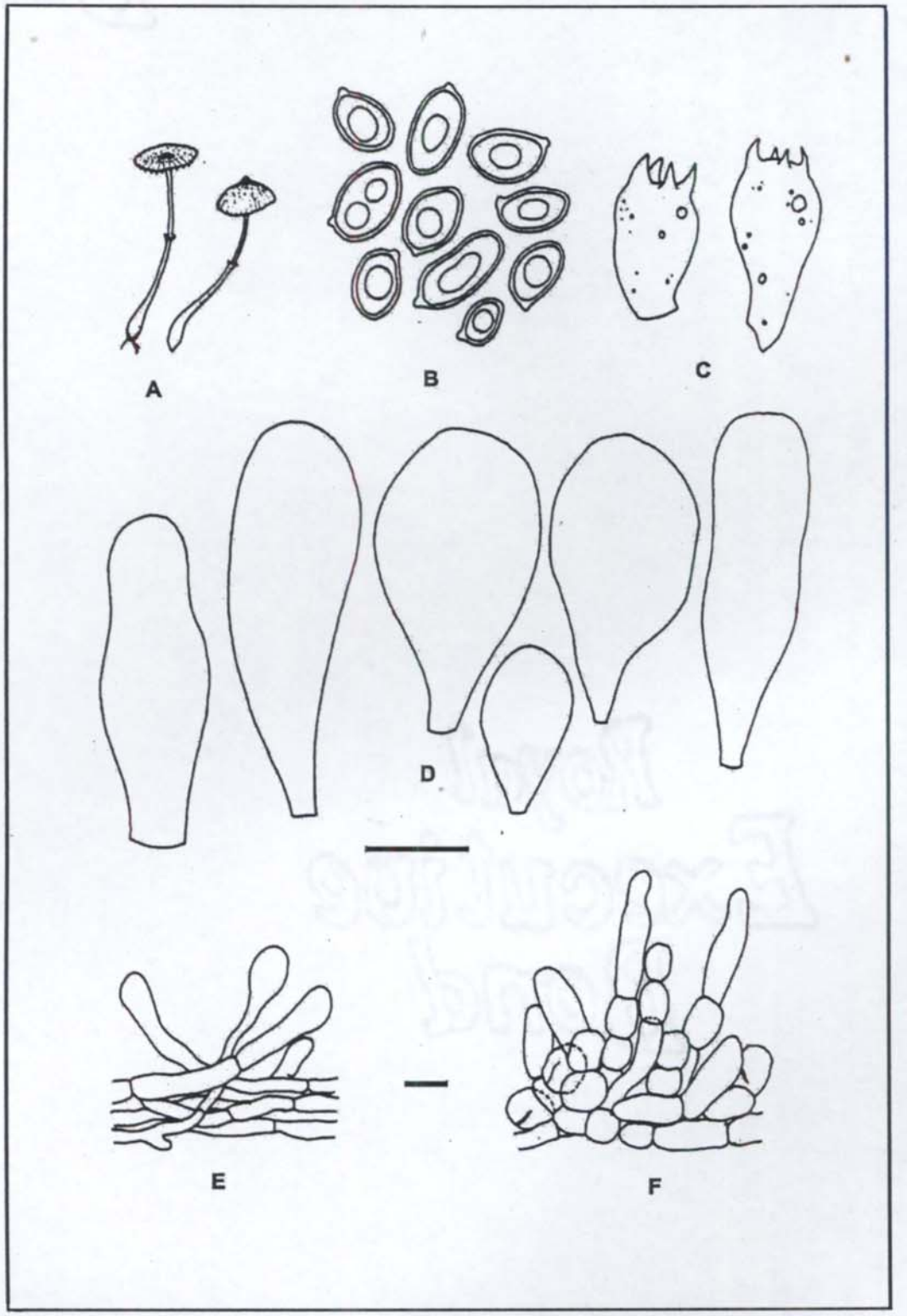


Figure 39. *Leucocoprinus submontagnei* **A.** Habit x 1 **B.** Spores **C.** Basidia **D.** Cheilocystidia **E.** Stipe covering **F.** Pileus covering. Bars = 10 µm.

Plate 37. *Leucocoprinus jubilaei* x 6

Plate 38. *Leucocoprinus submontagnei* x 3.5

Leucocoprinus straminellus (Baglietto) Narducci & Caroti in Memorie della Società Toscana di Scienze Naturali, Series B 102: 49 ('1995') (1996)

Agaricus straminellus Baglietto in Società crittogamologica italiana. Commentario 2: 263 (1865)

Lepiota straminella (Baglietto) Saccardo in Sylloge Fungorum 5: 44 (1887)

Lepiota cepaestipes variety *straminella* (Baglietto) Konrad & Maublanc in Icones selectae fungorum 6: 41 (1924)

- *Agaricus denudatus* Rabenhorst in Hedwigia 6: 45 (1867)

Lepiota denudata (Rabenhorst) Saccardo in Sylloge Fungorum 5: 52 (1887)

Leucocoprinus denudatus (Rabenhorst) Singer in Lilloa 22: 424 ('1949') (1951)

- *Lepiota boudieri* Guéguen in Bulletin trimestrial de la Société mycologique de France 24: 131 ('1908') (1909), non *Lepiota boudieri* Bresadola (1884)

Lepiota gueguenii Saccardo & Trotter in Saccardo, Sylloge Fungorum 21: 21 (1912)

Fig. 40. A-F; Pl. 39.

Basidiomata small. **Pileus** 12-15 mm diam., conico-convex when young, becoming broadly convex to applanate, with an indistinct umbo; surface whitish to yellowish white (4A2) with scattered, dark brown (9F5), granular squamules concentrated towards the disc and sparser towards the margin, fibrillose, sulcate-striate towards margin; margin initially incurved, later straight, entire. **Lamellae** free, yellowish white (4A2), crowded, up to 1.5 mm wide, with lamellulae in 2-3 tiers; edge finely fimbriate under a lens, concolorous with the sides. **Stipe** 30-50 × 1 mm, central, terete, almost

equal, slightly expanded towards base, hollow; surface concolorous with the pileus, fibrillose. **Annulus** not observed. **Context** less than 1 mm thick, yellowish white (4A2). **Odour** slightly unpleasant. **Spore-print** not obtained.

Spores 5-6.5 × 3.5-4.5 (5.5 ± 0.47 × 4 ± 0.17) µm, Q = 1.25-1.6, Qm = 0.98, ellipsoid, broadly ellipsoid or rarely subglobose, hyaline, with refractive guttules, thick-walled, smooth, dextrinoid, metachromatic in cresyl blue, cyanophilic in cotton blue. **Basidia** 10-15 × 7-12 µm, short clavate, with guttulate contents, hyaline, bearing 4 sterigmata up to 4 µm long. **Lamella-edge** sterile. **Cheilocystidia** 16-37 × 8-16 µm, cylindrical, clavate or broadly clavate, hyaline, thin-walled. **Pleurocystidia** not observed. **Lamellar trama** subregular; hyphae 2-12 µm wide, slightly inflated, septate, hyaline, thin-walled, inamyloid. **Subhymenium** cellular. **Pseudoparaphyses** present. **Pileal trama** interwoven; hyphae 4-20 µm wide, inflated, septate, thin-walled, hyaline, inamyloid. **Pileal covering** a cutis disrupted by epithelial patches of loosely attached sphaerocysts, 10-25 µm diam., thin-walled and with brown or grey to dark grey plasmatic pigment; entirely irregularly epithelial towards the disc. **Stipe covering** a cutis of 2-10 µm wide, hyaline to pale grey, thin- to slightly thick-walled hyphae occasionally disrupted by erect or ascending, cylindrical terminal elements. All hypahe devoid of clamp-connections.

Habitat: On soil, among decaying leaf litter, scattered.

Known Distribution: ASIA, Argentina, Brazil, EUROPE, Philippines, Venezuela

Collection examined — Calicut District, Peruvannamuzhi: 25 May 2004, AK34.

This species of *Leucocoprinus* has granular squamules scattered on a whitish to yellowish white pileal background, distinct striations towards the margin, and a pileal covering with epithelial patches of sphaerocysts. Characters of the present collection agree with the description of the species by Vellinga (2001c) except for the dark brown coloured squamules, smaller spores and the absence of lageniform cheilocystidia. Annulus was not observed in the Kerala collection. *Leucocoprinus straminellus* is considered to be identical with the well-known *L. denudatus* ((Rabenhorst) Singer (Vellinga 2001c). A comparison with a colour photograph of *L. denudatus* by Migliozzi *et al.* (1989a) indicates an overall macroscopic similarity except for the more yellowish pileus with concolorous squamules. Inspite of such a colour variation of squamules, a similarity in microscopical details is evident from the accompanying description. *Leucocoprinus cygneus* (Lange) Bon is a related species with white lamellae, amygdaliform spores, larger cheilocystidia that are mostly lageniform and reaching up to 100 µm long, and pileal elements with encrusting pigments. *Leucocoprinus submontagnei* Heinemann has white lamellae and much larger spores ((5.4) 6.5-8.1 (9.0) × 4.2-5.1, from the original account by Heinemann 1977a). *Lepiota micropholis* (Berkeley & Broome) Saccardo with a plicate-striate pileus differs chiefly in

having larger basidiomata, persistent annulus and in missing sphaerocysts in the pileal covering.

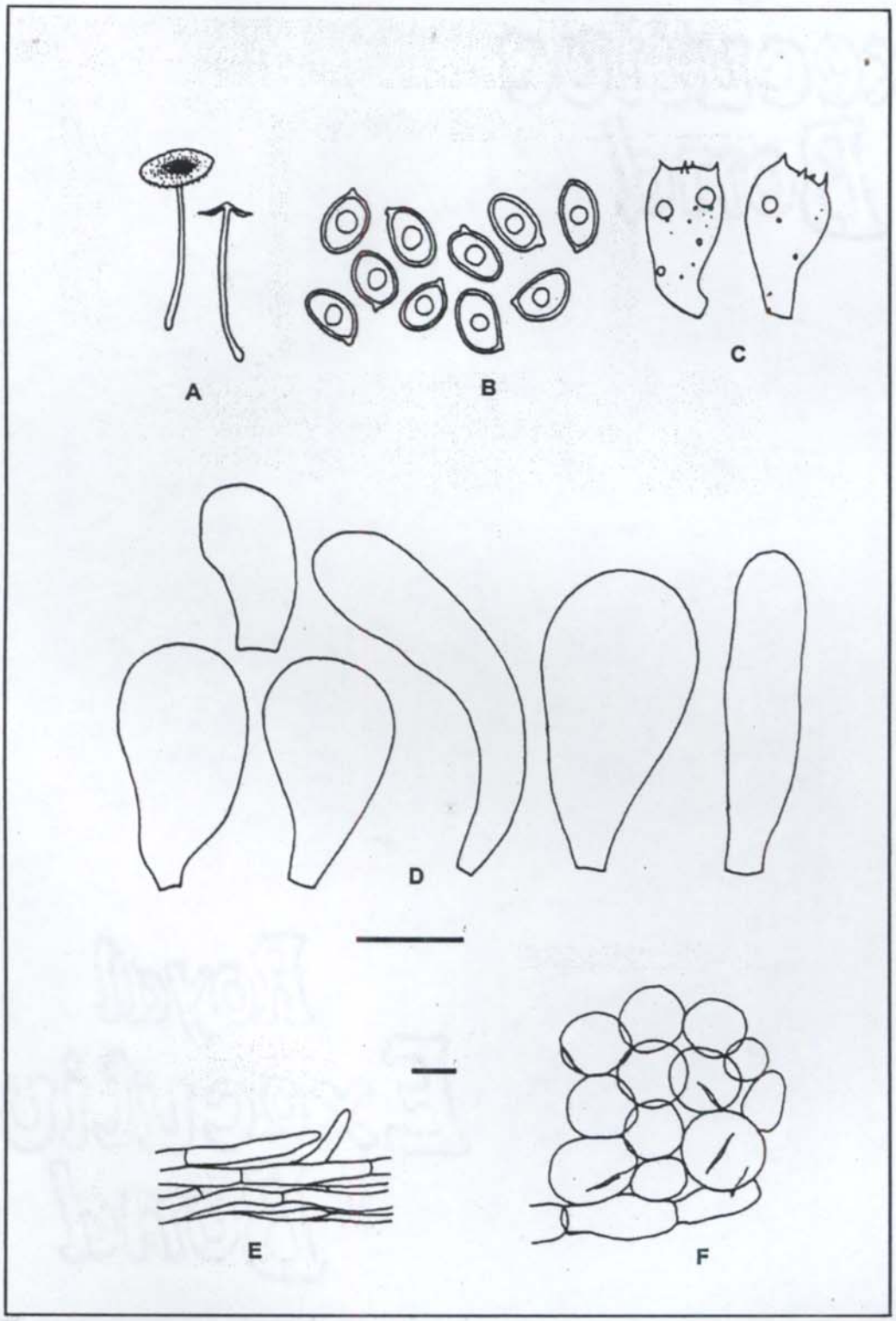


Figure40. *Leucocoprinus straminellus* **A.** Habit x 1 **B.** Spores **C.** Basidia **D.** Cheilocystidia **E.** Stipe covering **F.** Pileus covering. Bars = 10 µm

5.1.4 ***Leucoagaricus*** (Locquin) Singer

Leucocoprinus subgenus *Leucoagaricus* Locquin in Bulletin mensuel de la Société Linnéenne de Lyon 12: 92 (1943) not valid

Leucoagaricus (Locquin) Singer in Sydowia 2: 35 (1948)

Sericeomyces Heinemann in Bulletin de Jardin botanique national de Belgique 48: 401 (1978)

Basidiomata small to large, fragile to fleshy; pileal margin non-striate or rarely finely striate; lamellae free, mostly with a concolorous edge; stipe central, almost equal, with a slight expansion towards the base, distinctly bulbous in some, smooth, fibrillose or with distinct squamules; annulus mostly membranous, initially fixed, becoming movable with age; context in many species changing colour on exposure, bruising or with age; spore-print pure white to yellowish; spores small to large, cylindrical, ovoid, ellipsoid, amygdaliform, dextrinoid, metachromatic in cresyl blue, germ-pore present or absent, smooth, hyaline, slightly thick- to thick-walled; pseudoparaphyses absent; cheilocystidia present or rarely absent; pleurocystidia not present; lamellar trama regular to subregular, of inflated hyphae; pileal covering variable; stipe covering almost similar to that of the pileus; clamp-connections very rare or almost absent.

Type species: *Leucoagaricus macrorhizus* Locquin ex Horak.

5.1.4.1 KEYS TO THE SECTIONS AND SPECIES OF *LEUCOAGARICUS* IN KERALA

1. Spores with a distinct germ-pore ..... (Section *Annulati*) **3**
1. Spores lacking a germ-pore or else with a rudimentary one..... **2**
2. Pileus usually red, brown, ochre, olive or orange pigmented; pileal covering a cutis of repent hyphae..... (Section *Rubrotincti*) **5**
2. Pileus differently and lightly pigmented; pileal covering a disrupted cutis with ascending or erect terminal elements.... (Section *Leucoagaricus*) **8**
3. Basidiomata large; lamella-edge spotted dark brown; spores more than 10 µm long; cheilocystidia and terminal elements of pileal covering with apical prolongation..... ***Leucoagaricus* species 5**
3. Basidiomata small to medium-sized; lamella-edge concolorous with the sides; spores less than 10 µm long; cheilocystidia and terminal elements of pileal covering without apical prolongation..... **4**
4. Basidiomata medium-sized; pileus whitish to light orange with brownish red squamules; annulus fixed and with a coloured rim; pileal elements without encrusting pigments ..... ***Leucoagaricus* species 3**
4. Basidiomata small; pileus whitish with brown to dark brown squamules; annulus movable and without a coloured rim; pileal elements with encrusting pigments..... ***Leucoagaricus* species 6**
5. Pileus orange, brownish orange, brown or reddish brown..... **6**
5. Pileus not orange, brownish orange, brown or reddish brown..... **7**
6. Basidiomata small and somewhat delicate; pileal covering with two distinct layers..... ***Leucoagaricus glabridiscus***
6. Basidiomata small to medium-sized and rather robust; pileal covering single layered..... ***Leucoagaricus rubrotinctus***
7. Basidiomata pastel yellow, turning olive to dark grey on bruising; cheilocystidia ventricose, utriform or broadly clavate with apical prolongation..... ***'Lepiota viridiflava'***

7. Basidiomata white, not turning olive to dark grey on bruising; cheilocystidia narrowly clavate to clavate, cylindrical, ellipsoid, obovoid or rarely utriform without apical prolongation ..... ***Leucoagaricus* species 4**

8. Pileus yellow; context yellow; spores 4-7 × 2.5-3.5 µm, amygdaliform .... ***Leucoagaricus* species 2**

8. Pileus white; context white; spores 6-11 × 5-7.5 µm, ellipsoid, broadly ellipsoid, ovoid or globose ..... ***Leucoagaricus* species 1**

5.1.4.1.1 Section ***Annulati*** (Fries) Singer in Beihefte zur Sydowia 7: 213 (1973)

Species mostly fleshy; germ-pore distinct, at times covered with a hyaline cap; context either unchanging or yellowing, browning or reddening when bruised.

Type species: *Agaricus naucinus* Fries.

***Leucoagaricus* species 5**

Fig. 41. A-F; Pl. 40.

Basidiomata large. **Pileus** 80-85 mm diam., convex when young, becoming applanate and finally concave with an upturned margin, with a low umbo; surface whitish with brown (7E8) to dark brown (7F8) fibrillose squamules radiating from the disc in broken concentric circles; disc pruinose to granular, finely striate towards the margin; margin initially incurved, becoming straight, eroded. **Lamellae** free, whitish, crowded, up to 7 mm wide, with lamellulae in 4-5 tiers; edge finely fimbriate to denticulate, with

dark brown spots. **Stipe** 113-125 × 9-13 mm, central, terete, almost equal or expanding towards the base, fistulose; surface whitish with brown (7E8) squamules, turning light brown (5D5) on bruising and dark brown on drying, densely fibrillose to villose; base arising from a white mycelium. **Annulus** not observed. **Context** up to 3.5 mm thick, white. **Odour** not distinctive. **Spore-print** white.

Spores 10-15 × 7-9 (11.7 ± 1.4 × 7.7 ± 0.77) µm, Q = 1.3-1.9, Qm = 1.5, ovoid, ellipsoid to broadly ellipsoid or rarely amygdaliform, hyaline, with a germ-pore up to 1 µm broad or often inconspicuous, with refractive guttules, thick-walled (up to 1.5 µm), smooth, dextrinoid, distinctly metachromatic in cresyl blue, cyanophilous in cotton blue. **Basidia** 29-37 × 11-13 µm, clavate, with guttulate contents, hyaline, bearing 4 sterigmata up to 7.5 µm long. **Lamella-edge** sterile. **Cheilocystidia** abundant, 17-75 × 6-30 µm, clavate, obovoid, utriform, or lageniform, mostly with apical prolongations up to 35 µm long, thin-walled, pale yellowish brown to dark grey. **Pleurocystidia** none. **Lamellar trama** subregular; hyphae 2-8 µm, inflated up to 29 µm wide, loosely attached, hyaline to pale grey, thin-walled, inamyloid. **Subhymenium** cellular. **Pileal trama** interwoven; hyphae 2-23 µm wide, cylindrical, septate, hyaline, thin- to slightly thick-walled, inamyloid. **Pileal covering** mostly a cutis disrupted at the scales and towards the centre by trichodermial patches, entirely trichodermial at the disc; terminal elements 36-117 × 4-27 µm, clavate, utriform, or lageniform and mostly with one or more constrictions and having apical prolongations which are usually flexuose or moniliform, thick-walled (up to 1 µm), with brown to dark brown

membrane and plasmatic pigments. **Stipe covering** a cutis of 5-40 µm wide, hyaline to pale brown, slightly thick- to thick-walled (up to 2µm) hyphae; terminal elements 26-108 × 10-28 µm, cystidioid, clavate, utriform, lageniform, ovoid, most with apical prolongation, thick-walled, brown to dark brown plasmatic and membrane pigmented. Clamp-connections present, observed mainly on hyphae of pileus and stipe covering and very rarely at the base of cheilocystidia.

Habitat: On decomposing saw dust, solitary.

Known Distribution: Only from the type locality.

Collections examined — Calicut District, Arayedathupalam: 19 August 2005, AK384.

This species is distinguished by large and fleshy basidiomata, spores that are larger than 10 µm in length, trichodermial pileal covering, and clamp-connections. A combination of these and other characters makes an exact generic placement (between the genera *Leucoagaricus* and *Macrolepiota)* rather difficult. Based on a comparative evaluation of available and accepted morphological criteria, the species is considered here under the genus *Leucoagaricus*. The large-sized basidiomata and large spores indicate genus *Macrolepiota*, although no strict size-based demarcation for members of *Leucoagaricus* have been set. Singer (1986) considered

Leucoagaricus specimens larger than '12.5 cm' as rare. However, several large-sized taxa with pilei even up to 20 mm diameter (e.g. *L. leucothites*) are admitted. Candusso & Lanzoni (1990) considered a minimum size of 'over 10 cm' to be qualified under *Macrolepiota.* Large spore sizes (more than 10 µm) are not exclusive to members of *Macrolepiota* as many *Leucoagaricus* (spores mostly less than 10 µm long according to Reid & Eichler 1993a) and *Leucocoprinus* species (medium to large, Reid & Eichler 1993a) also possess large spores. The marginate lamella-edge, crowded with dark brown cheilocystidia having characteristic apical prolongations is reminiscent of those of the *Leucocoprinus badhamii* group with rubescent flesh. Stipe context of the present collection turn light brown (5D5) on bruising and dark brown on drying (an attribute also observed in *Macrolepiota* species), but a greenish colour reaction with ammonia typical of the '*badhamii*' group is absent. Finally, a consideration inside the genus *Leucocoprinus* could be ruled out as pseudoparaphyses in the hymenium are not observed.

While all these justify a putative placement inside *Leucoagaricus*, an important character that becomes a stumbling block is the presence of clamp-connections. In this species, clamp-connections are neither absent nor rare but on the contrary are even prominent and rather frequent in the hyphae of pileal and stipe covering. Since Singer (1986) avers the absence of clamp-connections as a distinctive feature of the genus *Leucoagaricus*, this character in the present species is strongly suggestive of a *Macrolepiota* link. In *Macrolepiota*, clamps are admissible as per the accepted morphology

based generic concepts. However, a placement under *Macrolepiota* accepting the presence of clamp-connections as a more valuable feature does not seem suitable either. The current placement of this enigmatic species in the genus *Leucoagaricus* warrants further morphological and molecular confirmations. Such investigations could reveal more decisive data regarding taxonomic placements and concepts, as in the case of the disputed *Leucoagaricus hortensis* (Murrill) Pegler (refer Akers & Sundberg 1997; Vellinga 2003c, 2004a).

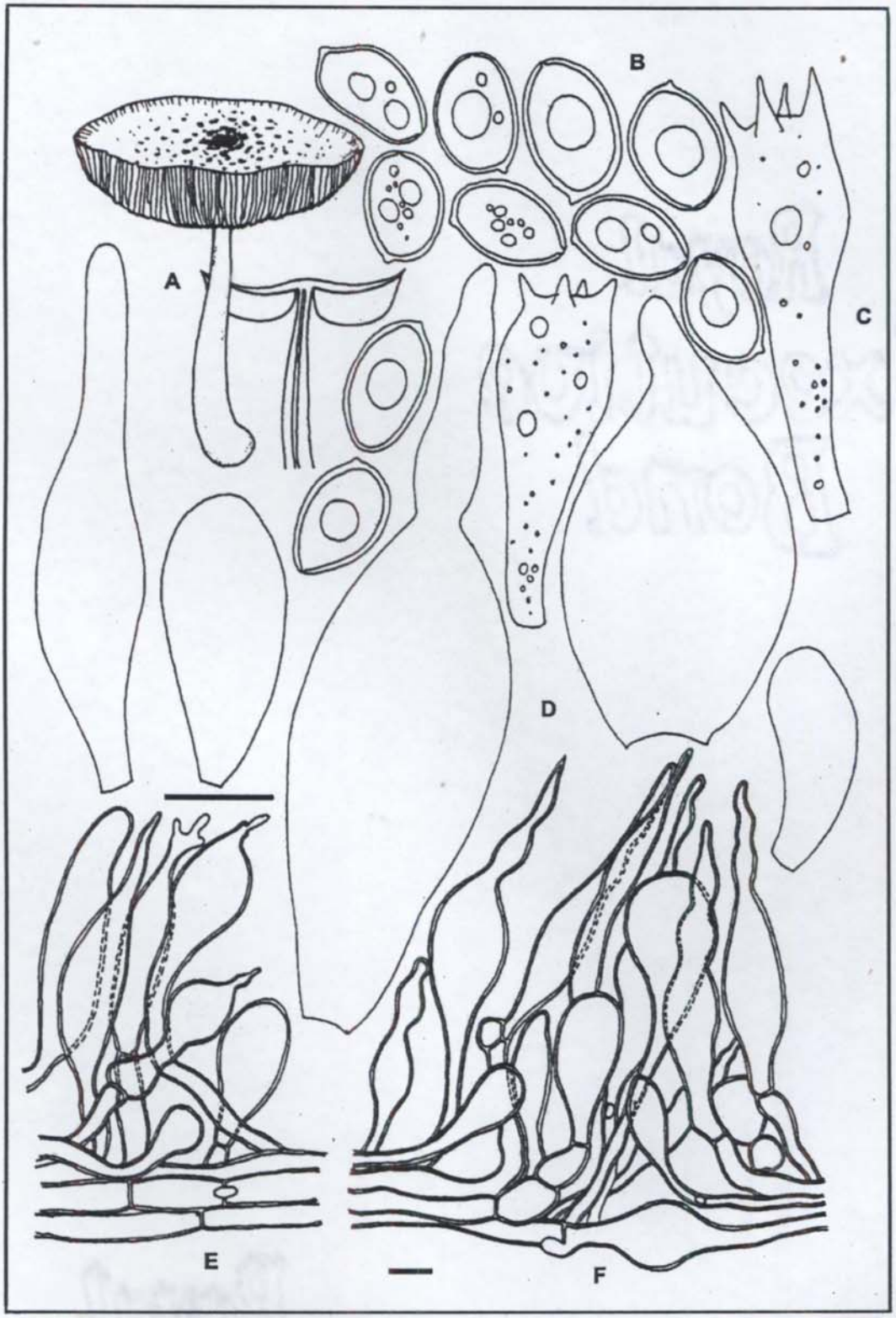


Figure 41. *Leucoagaricus* species 5 **A.** Habit x 1 **B.** Spores **C.** Basidia **D.** Cheilocystidia **E.** Stipe covering **F.** Pileus covering. Bars = 10 µm.

Plate 39. *Leucocoprinus straminellus* x 5

Plate 40. *Leucoagaricus* species 5 x 1

***Leucoagaricus* species 3**

Fig. 42. A-F; Pl. 41.

Basidiomata medium-sized. **Pileus** 45 mm diam., initially convex, becoming broadly convex and finally applanate, with a broad umbo at the disc; surface whitish to light orange (6A4), with minute, brownish red (8C8), scattered, appressed-fibrillose squamules that are sparser towards the margin, pruinose to more or less smooth at the disc, finely striate at the margin; margin initially incurved, becoming straight, eroded. **Lamellae** free, whitish, crowded, up to 9 mm wide, with lamellulae in 3-4 tiers; edge fimbriate under a lens, concolorous with the sides. **Stipe** 42 × 3.5 mm, central, terete, equal, slightly bulbous at the base, initially solid, becoming fistulose with age; surface whitish to pale yellow (4A3), turning greyish orange (5B4) on bruising or with age, fibrillose; base arising from a white mycelium. **Annulus** superior, membranous, simple, ascending, fixed, with a rim covered with brownish red (8C8) fibrils. **Context** up to 1.5 mm thick, white. **Odour** not distinctive. **Spore-print** not obtained.

Spores 6.5-9 × 4-5 (7.8 ± 0.63 × 4 ± 0.44) µm, Q = 1.5-2.25, Qm = 2, oblong-ellipsoid, subcylindrical, amygdaliform, or more or less fusiform with a slight suprahilar depression, often with a germ-pore 0.5 to 1 µm broad and covered with an indistinct hyaline cap, hyaline, with refractive guttules, thick-walled (up to 1 µm), smooth, dextrinoid, metachromatic in cresyl blue, cyanophilous in cotton blue. **Basidia** 10-17 × 7-8 µm, almost ovoid to short

clavate, hyaline, bearing 4 short sterigmata up to 2 µm long. **Lamella-edge** sterile. **Cheilocystidia** crowded, 16-40 × 7-15 µm, cylindrical, cylindrico-clavate, clavate, broadly clavate, or utriform, thin-walled, hyaline. **Pleurocystidia** absent. **Lamellar trama** subregular; hyphae 5-13 µm wide, inflated, hyaline, thin-walled, inamyloid. **Subhymenium** cellular. **Pileal trama** interwoven; hyphae 2-25 µm wide, inflated, hyaline, thin-walled, inamyloid. **Pileal covering** a cutis of repent cylindrical hyphae disrupted by trichodermial patches of ascending or erect, loosely attached terminal elements; terminal elements 20-110 × 5-18 µm, cylindrical, cylindrico-clavate or ellipsoid, slightly thich- to thick-walled (up to 1 µm), with pale brown to brown plasmatic and membrane pigments. **Stipe covering** a cutis of repent hyphae with occasionally ascending hyphal filaments; hyphae 2-8 µm wide, thin-walled, hyaline. Clamp-connections not observed.

Habitat: On soil, solitary.

Known Distribution: Only from the type locality.

Collections examined — Wayanad District, Muthanga: 2 June 2005, AK222.

This species is characterized by a pileus with brownish red squamules on a whitish to light orange background; oblong-ellipsoid, subcylindrical or amygdaliform spores with germ-pore covered by an

indistionct hyaline cap; versiform cheilocystidia; and a pileal covering with loosely attached cylindrical, cylindrico-clavate or ellipsoid terminal elements. Since pseudoparaphyses were not observed in the hymenium, this species is treated as belonging to the genus *Leucoagaricus*. Except for the persistant annulus on the stipe, spores with a germ-pore, short basidia, clavate, broadly clavate, utriform or cylindrical cheilocystidia and by the lack of any encrusting pigments on the terminal elements on pileal covering, it is similar to *Leucoagaricus tener* (Orton) Bon. Since the combination of characters of the present species does not exactly match any available descriptions, the species is considered as new to science.

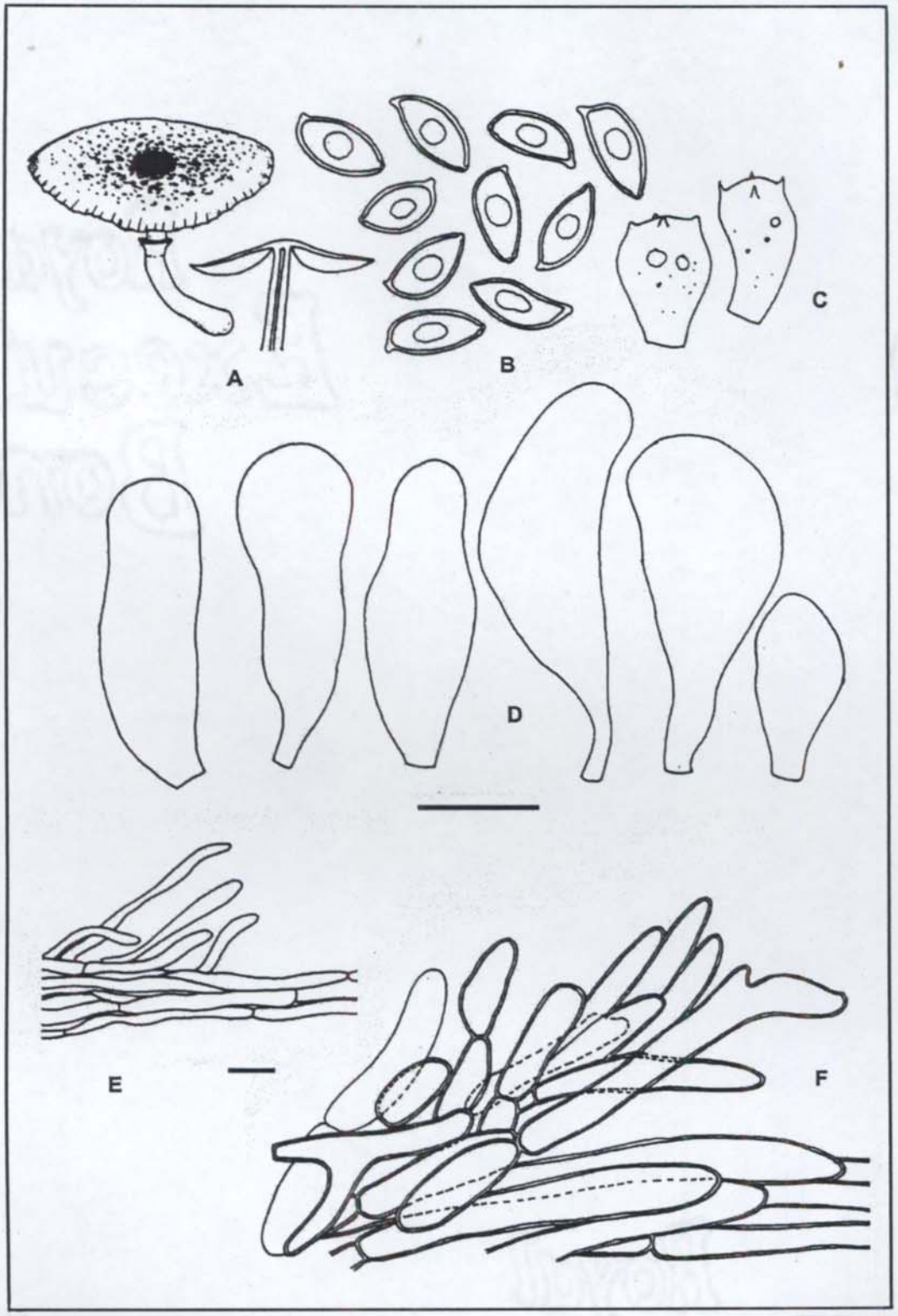


Figure 42. *Leucoagaricus* species 3 **A.** Habit x 1 **B.** Spores **C.** Basidia **D.** Cheilocystidia **E.** Stipe covering **F.** Pileus covering. Bars = 10 µm.

***Leucoagaricus* species 6**

Fig. 43. A-F; Pl. 42.

Basidiomata small. **Pileus** 9-19 mm diam., initially convex, becoming broadly convex to applanate, finally turning slightly depressed, with a low or sometimes prominent umbo; surface whitish to dull white, dotted with minute, brown (7E5, 7E6) to reddish brown (8E8) or dark brown (7F7, 8F8), appressed-fibrillose squamules, pruinose to more or less smooth towards the disc; margin initially incurved, later becoming straight, entire. **Lamellae** free, initially whitish, slowly turning yellowish white (2A2) to light brown (6D7) and finally brown (7E5) on bruising, drying or with age, moderately crowded to crowded, up to 2 mm wide, with lamellulae in 2-4 tiers; edge finely fimbriate under a lens, concolorous with the sides. **Stipe** 25-38 × 1-2 mm, central, terete, equal, slightly bulbous at the base, initially solid, becoming fistulose; surface whitish, turning light brown (6D7) to brown (7E5) on bruising or on drying, almost glabrous or slightly fibrillose; base arising from a white mycelium. **Annulus** almost central or superior, membranous, simple, ascending, movable, evanescent. **Context** up to 1 mm thick, whitish, changing to light brown (6D7), and gradually brown (7E5) on exposure. **Odour** not distinctive. **Spore-print** white.

Spores 5-10 × 3.5-5.5 (6.7 ± 0.89 × 4 ± 0.54) µm, Q = 1.3-1.8, Qm = 1.5, ellipsoid, ovo-ellipsoid, ovoid or amygdaliform, with an inconspicuous or distinct germ-pore up to 1 µm broad, hyaline, with refractive guttules,

somewhat thick-walled (up to 1 µm), smooth, dextrinoid, metachromatic in cresyl blue, cyanophilous in cotton blue. **Basidia** 13-24 × 8-10 µm, clavate to broadly clavate, hyaline, bearing 4 sterigmata up to 5 µm long. **Lamella-edge** sterile. **Cheilocystidia** crowded, 10-75 × 7-12 µm, cylindric, cylindrico-clavate, clavate, broadly clavate, utriform, ventricose, fusoid, broadly fusoid, or rarely strangulated, mostly septate, thin- to thick-walled (up to 1 µm), with fine guttulate contents and often with fine granular exudates on the surface, hyaline. **Pleurocystidia** absent. **Lamellar trama** subregular; hyphae 2-25 µm wide, inflated, hyaline, thin- to slightly thick-walled, inamyloid. **Subhymenium** cellular. **Pileal trama** interwoven; hyphae 3-40 µm wide, inflated, hyaline, thin-walled, inamyloid. **Pileal covering** a repent cutis composed of 3-10 µm wide, slightly thick- to thick-walled (up to 1 µm) hyphae towards the margin, highly disrupted towards the centre and forming a trichodermium at the disc with ascending or erect terminal cells; terminal cells short, ellipsoid to cylindrical, 3-12 µm wide, thick-walled (up to 1 µm), with brown to dark brown plasmatic, membrane and encrusting pigments. **Stipe covering** a cutis of repent hyphae with occasional ascending hyphae; hyphae 3-10 µm wide, thin- to slightly thick-walled, with hyaline to pale brownish plasmatic pigment. Clamp-connections rare, observed on hyphae of pileal covering.

Habitat: On soil, solitary.

Known Distribution: Only from the type locality.

Collections examined — Malappuram District, Calicut University Campus: 26 June 2006, AK398; 10 July 2006, AK415; 26 September 2006, AK443; 27 September 2006, AK448.

Distinctive characters of this rather small species are a whitish pileus with brown fibrillose squamules, lamellae and stipe that turn light brown to brown on bruising, ellipsoid spores with a germ-pore, thick-walled cheilocystidia with fine granular exudates, and a cutis-type pileal covering that becomes trichodermial towards the disc, with ascending or erect short ellipsoid to cylindrical terminal elements having plasmatic, membrane and encrusting pigments. Another remarkable observation is the rare occurrance of clamp-connections. Clamp-connections are considered uncharacteristic of the genus *Leucoagaricus*. But since the spores of this species possess a noticeable germ-pore and additionally exhibit a typical metachromatic reaction with cresyl blue, it is considered as belonging to that genus. *Leucoagaricus crystallifer* Vellinga appears to be a species with somewhat similar characters (Vellinga 2000b; 2001b). That species, however, differs by its slightly larger basidiomata that produce apically papillate spores without germ-pore. Furthermore, the pileal elements in *L. crystallifer* have different terminal cells. The primary character that differentiates other similar species like *L. sericifer* (Locquin) Vellinga and *L. sublittoralis* (Kühner ex Hora) Singer is the ellipsoid spores with a germ-pore in the present species. The present collections represent a hitherto undescribed species.

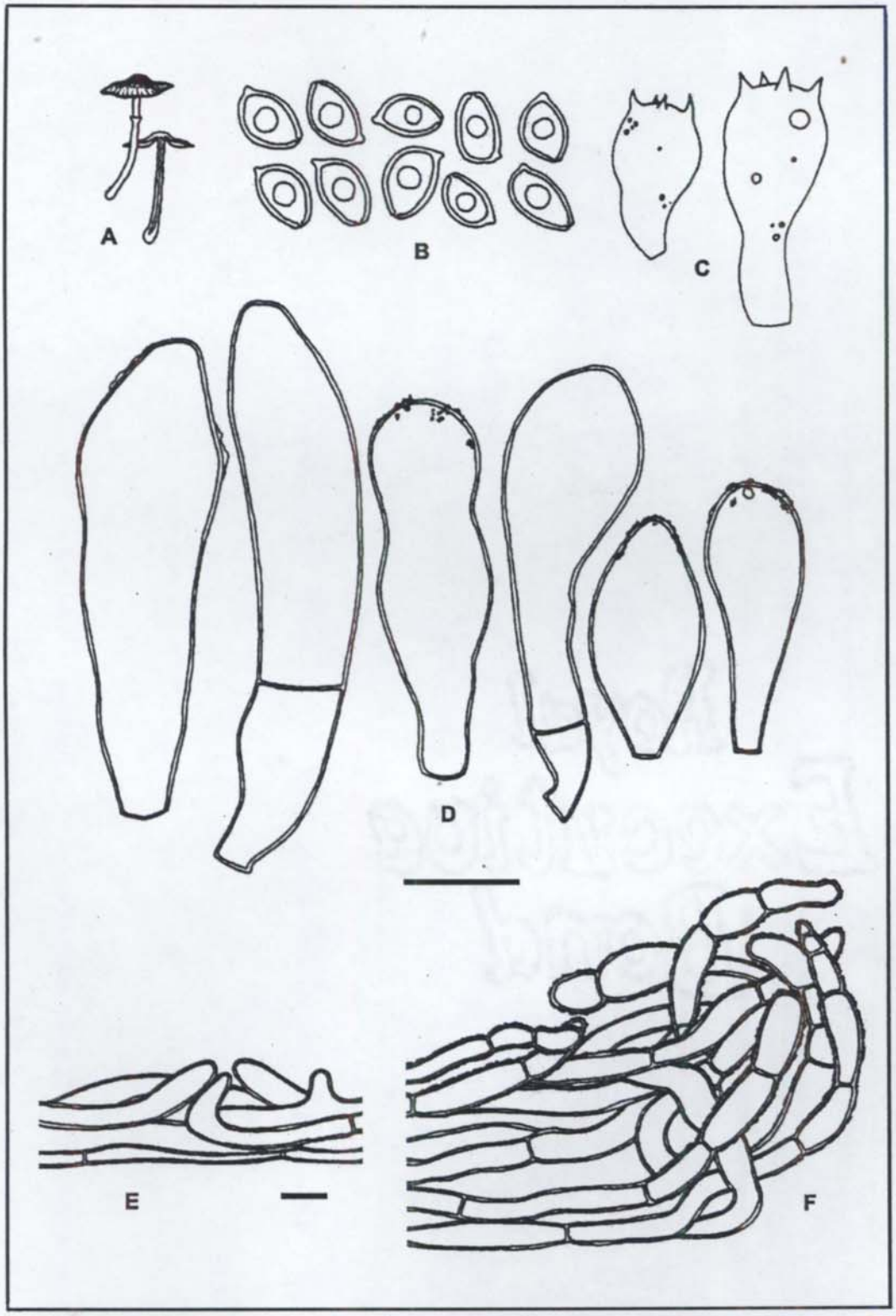


Figure 43. *Leucoagaricus* species 6 **A.** Habit x 1 **B.** Spores **C.** Basidia **D.** Cheilocystidia **E.** Stipe covering **F.** Pileus covering. Bars = 10 µm.

Plate 41. *Leucoagaricus* species 3 x 3

Plate 42. *Leucoagaricus* species 6 x 5

5.1.4.1.2 Section ***Rubrotincti*** Singer in Sydowia 2: 36 (1948)

Basidiomata more or less fleshy, usually with red, brown, orange or olive pileus; Spores without germ-pore or with a rudimentary one.

Type species: *Leucoagaricus rubrotinctus* (Peck) Singer

Leucoagaricus glabridiscus (Sundberg) Wuilbaut in Documents Mycologiques 17 (65): 46 (1986)

Lepiota glabridisca Sundberg in Mycotaxon 8: 447 (1979)

Fig. 44. A-F; Pl. 43.

Basidiomata small. **Pileus** 22-50 mm diam., convex when young, becoming broadly convex to applanate, distinctly umbonate at the disc; surface reddish brown (8E6, 8E7) at the disc and brownish orange (7C5, 7C6) elsewhere, covered with a dry, thin, glabrous cuticle, smooth at the disc, radially cracking towards the margin and peeling off as a layer revealing the white context below; margin initially incurved, becoming straight, entire. **Lamellae** free, white, crowded, up to 5 mm wide, with lamellulae in 5-6 tiers; edge fimbriate under a lens, concolorous with the sides. **Stipe** 25-73 × 2-5 mm, central, terete, almost equal, slightly bulbous at the base, fistulose; surface white changing to yellowish white (5D5) on bruising or with age, finely fibrillose; base arising from white mycelial cords. **Annulus** superior or rarely central, membranous, ascending, evanescent. **Context** up to 4 mm thick, white. **Odour** not distinctive. **Spore-print** not obtained.

Spores 6-8 × 3.5-4.5 (6.85 ± 0.63 × 4 ± 0.2) µm, Q = 1.5-2, Qm = 1.7, amygdaliform, rarely ellipsoid, hyaline, without a germ-pore, with refractive guttules, thick-walled (up to 1 µm), smooth, dextrinoid, metachromatic in cresyl blue, cyanophilous in cotton blue. **Basidia** 20-29 × 6-8 µm, clavate, with guttulate contents, hyaline, bearing 4 sterigmata up to 3 µm long. **Lamella-edge** sterile. **Cheilocystidia** crowded, 20-38 × 8-15 µm, cylindrical to clavate or utriform, occasionally with a subcapitate apex, thin-walled, hyaline. **Pleurocystidia** none. **Lamellar trama** subregular; hyphae 2-5 µm, inflated up to 25 µm wide, hyaline, thin-walled, inamyloid. **Subhymenium** cellular. **Pileal trama** interwoven; hyphae 2-25 µm wide, hyaline, thin-walled, inamyloid. **Pileal covering** bi-layered, composed of an agglutinated layer of 2-9 µm wide, cylindrical, thin-walled, pale orange to brown hyphae, that are irregular and highly interwoven and a non agglutinated interwoven layer below; terminal elements 70-100 × 3-9 µm, cylindrical, thin-walled, with pale brown to brownish plasmatic and membrane pigments. **Stipe covering** a cutis made up of repent, 2-6 µm wide, cylindrical, hyaline, thin-walled hyphae. Clamp-connections rarely observed.

Habitat: On humus rich soil on forest floor, solitary, scattered or gregarious.

Known Distribution: USA

Collections examined — Malappuram District, Calicut University Campus: 13 April 2005, AK212; 15 April 2005, AK212a; 3 June 2005, AK212b; 8 June 2005, AK212c; 27 June 2005, AK297.

Characters of these collections perfectly agree with the original description of the species from the Pacific coast of USA except for the density of lamellulae (5-6 tiers in the Kerala collections while only 1-2 tiers in the USA material), slightly smaller spore lengths (up to 10.3 µm in USA collections) and the very rarely observed clamp-connections. This species differs from the closely related *Leucoagaricus rubrotinctus* in having rather frail stature, smaller size and a double layered pileal covering of interwoven hyphae.

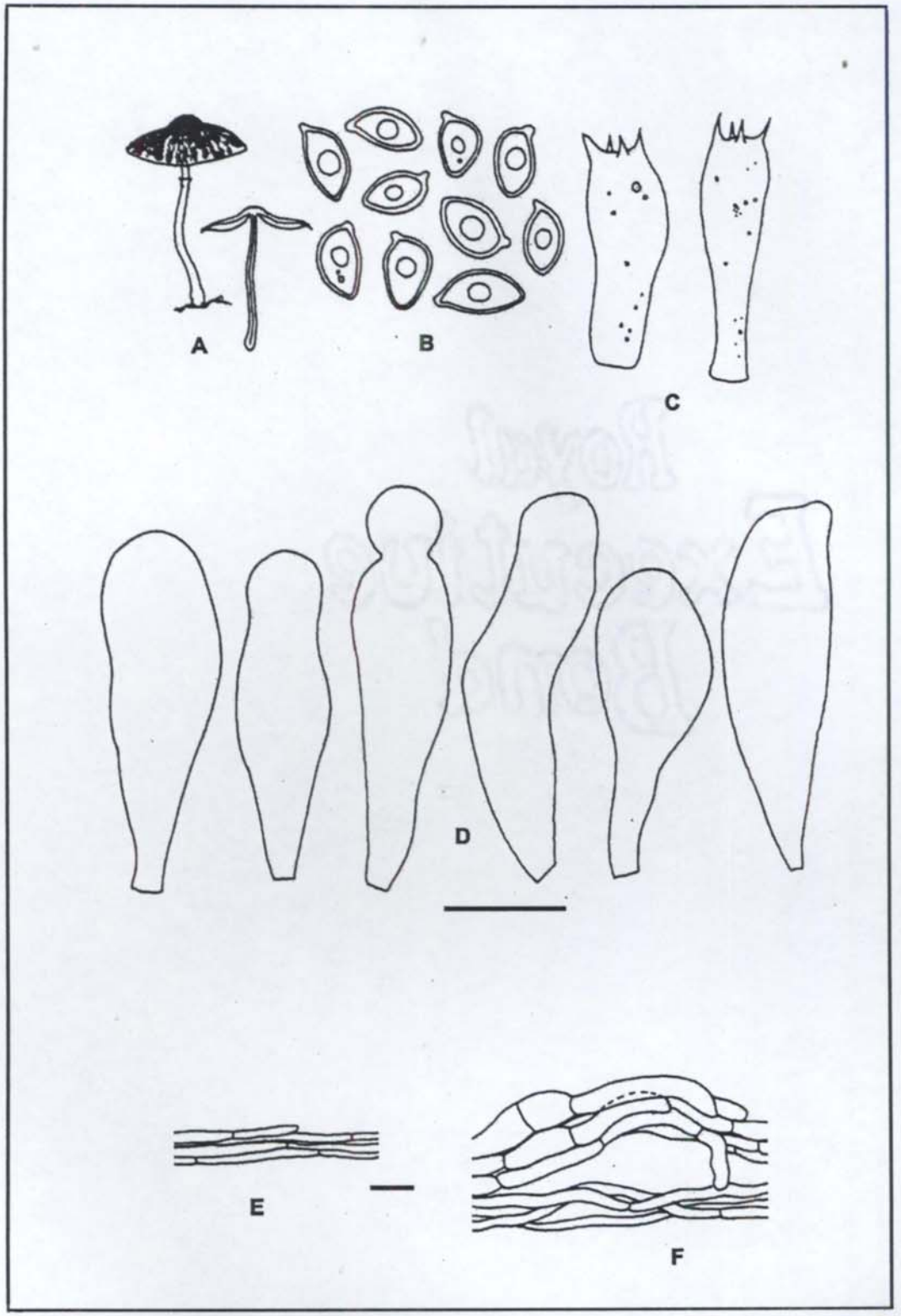


Figure 44. *Leucoagaricus glabridiscus* **A.** Habit x 1 **B.** Spores **C.** Basidia **D.** Cheilocystidia **E.** Stipe covering **F.** Pileus covering. Bars = 10 µm.

Leucoagaricus rubrotinctus (Peck) Singer in Sydowia 2: 36 (1948)

Agaricus rubrotinctus Peck in Annual Report on the New York State Museum of Natural History 35: 155 (1884)

Lepiota rubrotincta Peck in Annual Report on the New York State Museum of Natural History 44: 179 (1892)

Fig. 45. A-F; Pl. 44.

Basidiomata small to somewhat medium-sized. **Pileus** 29-54 mm diam., subglobose to parabolic when young, becoming convex to broadly convex and finally applanate, with an indistinct umbo; surface pale orange (5A3) or light orange (5A4, 5A5), darker towards the disc with shades of pastel red (7A4, 7A5), reddish orange (7B7) or brown (7E8) to dark brown (7F8), somewhat granular to pruinose or minutely fibrillose with slightly recurved squamules towards the margin, smooth at the disc; Pileal covering peeling off as a layer from the margin when old; margin initially incurved, later straight, entire to appendiculate, becoming slightly upturned and fissile with age. **Lamellae** free, white, crowded, up to 3-5 mm wide, with lamellulae in 3-5 tiers; edge finely fimbriate under a lens, concolorous with the sides. **Stipe** 40-140 × 4-7 mm (up to 10 mm at the base), central, terete, almost equal, slightly expanding or somewhat bulbous at the base, initially solid, becoming fistulose to almost hollow with age; surface whitish to pale yellow (4A3), with minute pale orange (5A3) squamules below the annulus, finely fibrillose; base arising from white mycelial cords. **Annulus** superior, membranous, ascending, with minute dark brown (7F8) squamules on the

rim, initially fixed, movable with age. **Context** up to 4 mm thick, white. **Odour** not distinctive. **Spore-print** white.

Spores 5-8 × 3.5-5 (6 ± 0.63 × 4 ±0.44) µm, Q = 1.3-1.7, Qm = 1.5, ellipsoid to broadly ellipsoid or rarely amygdaliform, hyaline, without a germ-pore, with refractive guttules, thick-walled (up to 1 µm), smooth, dextrinoid, metachromatic in cresyl blue, cyanophilous in cotton blue. **Basidia** 14-20 × 7-9 µm, clavate, with guttulate contents, hyaline, bearing 4 sterigmata up to 4 µm long. **Lamella-edge** sterile. **Cheilocystidia** crowded, 11-48 × 4-10 µm, versiform: cylindrical, clavate, lageniform, fusiform, flexuose, utriform, or ventricose-rostrate, some mucronate, rarely septate, thin-walled, hyaline, pale yellowish or brownish. **Pleurocystidia** none. **Lamellar trama** subregular; hyphae 2-16 µm wide, inflated up to 26 µm, hyaline to pale yellow, thin-walled, inamyloid. **Subhymenium** cellular. **Pileal trama** interwoven; hyphae 3-19 µm wide, slightly inflated, hyaline, thin- walled, inamyloid. **Pileal covering** a cutis of repent cylindrical hyphae; hyphae 2-8 µm wide, thin-walled and with hyaline to pale brown plasmatic pigment, slightly gelatinized at the disc. **Stipe covering** a cutis made up of 2-8 µm wide, hyaline, thin-walled hyphae with fine encrusting pigments. Clamp-connections absent.

Habitat: On soil among decaying leaf litter, solitary or scattered in groups.

Known Distribution: AFRICA, ASIA, the Lesser Antilles, Brazil, Canada, EUROPE, Mexico Switzerland, USA.

Collections examined — Calicut District, Puthiyangadi: 10 April 2005, AK208; Malappuram District, Calicut University Campus: 29 June 2005, AK323; 30 June 2005, AK323a; 8 July 2005, AK 345.

The present collections have characters that agree well with the published descriptions of *Leucoagaricus rubrotinctus*. This ubiquitous species is easily recognizable in the field by their shades of pale orange to reddish orange or dark brown colours of the pileal covering. Murrill (1912) differentiated this species from *Lepiota rubrotinctoides* Murrill, an extremely similar species, on account of the 'larger size, darker umbo, smaller spores, and the absence of scales on the surface of the pileus' of the latter.

'Lepiota viridiflava' Petch in Annals of the Royal Botanic Garden, Peradeniya 6: 195 (1917)

Fig. 46. A-F; Pl. 45.

Basidiomata small, all parts readily turning olive (1E4, 1E5) to dark olive (2F8) and finally dark grey (1F1) on bruising. **Pileus** 11-29 mm diam., conico-convex when young, becoming convex to applanate with age, somewhat broadly umbonate; surface pastel yellow (1A4, 1A5), glabrous or rarely with minute appressed concolorous or olive (1E4, 1E5) fibrils, non-striate; margin initially incurved, becoming straight, entire or sometimes with velar remnants, becoming fissile with age. **Lamellae** free, moderately crowded to crowded, up to 4 mm wide, pastel yellow (1A4, 1A5) to greenish yellow (1A7), with lamellulae in 2-4 tiers; edge finely fimbriate under a lens, greenish in older specimens. **Stipe** 40-70 × 2-4 mm, central, terete, almost equal and with a slightly bulbous base (up to 6mm wide), initially solid, becoming fistulose with age; surface pastel yellow (1A4, 1A5, 2A4), smooth, fibrillose towards base. **Annulus** superior, membranous, evanescent. **Context** up to 4 mm thick at the disc, pastel yellow (1A3), changing olive (1E5, 1E6) to dark olive (2F8) on exposure. **Odour** not distinctive. **Spore-print** not obtained.

Spores 5.5-8.5 × 4-5 (6.9 ± 0.79 × 4.4 ± 0.64) µm, Q = 1.4-1.8, Qm =1.64, ovo-ellipsoid to subamygdaliform with a truncated apex, with an inconspicuous germ-pore, with a pale green tinge or almost hyaline, with

refractive guttules, thick-walled, smooth, dextrinoid, metachromatic in cresyl blue, cyanophilous in cotton blue. **Basidia** 19-26 × 7.5-9 µm, clavate, with green vacuolar pigments, bearing 4 sterigmata up to 5 µm long. **Lamella-edge** sterile. **Cheilocystidia** crowded, 15-38 × 7-18 µm, utriform, ventricose or broadly clavate, thin-walled, mostly with an apical prolongation up to 16 µm long and 6 µm wide, often with amorphous contents and covered with similar exudates towards the apex, hyaline. **Pleurocystidia** absent. **Lamellar trama** subregular; hyphae inflated, septate, 2-20 µm wide, hyaline, thin-walled, inamyloid; **Subhymenium** cellular. **Pileal trama** parallel-interwoven; hyphae closely septate, inflated, 5-20 µm wide, hyaline to pale yellowish green, thin-walled, inamyloid, with obtuse tips. **Pileal covering** an undifferentiated cutis of repent, cylindric, septate, 3-12 µm wide, thin-walled, yellow or yellowish green to green pigmented hyphae. **Stipe covering** a cutis; hyphae 3-10 µm wide, thin-walled, with greenish plasmatic pigment. Clamp-connections very rarely observed in the hyphae of the pileal trama.

Habitat: On soil, among decaying *Acacia* leaves, solitary or scattered,

Known Distribution: Sri Lanka

Collections examined — Malappuram District, Calicut University Campus: 3 June 2004, AK45; 4 June 2004, AK47; 4 June 2004, AK45a; 8 June 2004, AK45b; 9 June 2004, AK52; 23 July 2004, AK80; 7 October 2004, AK 128; 10 November 2004, AK185; 10 November 2004, AK80a.

This species fruits widely and regularly in the Calicut University campus and adjoining areas around *Acacia* trees during short dry spells immediately after heavy rains. It has not been encountered so far from other parts of the State.

This species is remarkable for the olive green colouration on all parts of the basidiomata upon bruising. The species is furthermore characterized by its yellowish colour, an almost smooth pileus, non-striate pileal margin occasionally retaining velar fragments, a subbulbous base, evanescent annulus, somewhat thick yellow context changing to olive green on exposure, ovo-ellipsoid to subamygdaliform spores with a truncate apex having a highly inconspicuous germ-pore and showing metachromatism in cresyl blue and utriform, ventricose or broadly clavate cheilocystidia with long apical prolongations ornamented with amorphous encrustations. Clamp-connections are very rare but seen on occurring in the hyphae of the pileal trama of two specimens.

The characters of the present collections agree well with the original description of *Lepiota viridiflava* given by Petch (1917) based on material collected from Sri Lanka. Petch gave only a scanty description of the species with a somewhat adequate macroscopic description. The only microscopic data provided was on the size and shape of the spores. Microscopic data available from the present collections showed spores with an inconspicuous germ-pore difficult to distinguish, and exhibiting metachromatic reaction in the inner wall layer with cresyl blue (Plate 59. A & B.). The cheilocystidia were characterized by apical prolongations similar to those found in many

Leucoagaricus and *Leucocoprinus* species. Except for the extremely rare occurrence of clamp-connections, these characters of this species seem to favour a position inside the *Leucoagaricus/Leucocoprinus* complex, in contrast to its current placement in the genus *Lepiota*. The somewhat robust nature of the basidiomata, lack of distinct striations on the pileus and the absence of pseudoparaphyses in the hymenium keeps the species apart from *Leucocoprinus*. This species is treated under *Leucoagaricus* in this study on account of its combination of characters although futher confirmation of its exact taxonomic position on the basis of molecular data is warranted.

Petch (1917), in his original description of the species did not cite any type material. Stating that no material for this species could be traced for examination, Pegler (1972, 1986) entirely reproduced Petch's original account of the species in his subsequent floristic contributions from Sri Lanka, 'for the sake of completeness'. Quite recently, Akers *et al.* (2000) while describing a new species (*Leucoagaricus viridiflavoides*) from Florida with discussion on its affinities to its related taxa including *Lepiota viridiflava* mentioned the inability to locate any available representative collections of the latter species in herbaria. A thorough literature search also indicates that the species has not been collected since its original discovery from any part of the world or even from its type locality. As indicated by Akers *et al.*, an extant holotype for *L. viridiflava* seems lacking. Therefore, one of the present collections of the species from Kerala could serve as a neotype material. A formal proposal to this effect will be published elsewhere.

Leucoagaricus viridiflavoides and *L. sulphurellus* (Pegler) Akers are two closely related species characterized by a yellow flesh and a bluish green colour change on bruising. A study of the holotype material of the latter species by Akers *et al.* suggests its distinction from *L. viridiflava. L. viridiflavoides* could be distinguished from *L. viridiflava* on account of spore size, presence of pleurocystidia and shape of elements of pileal covering.

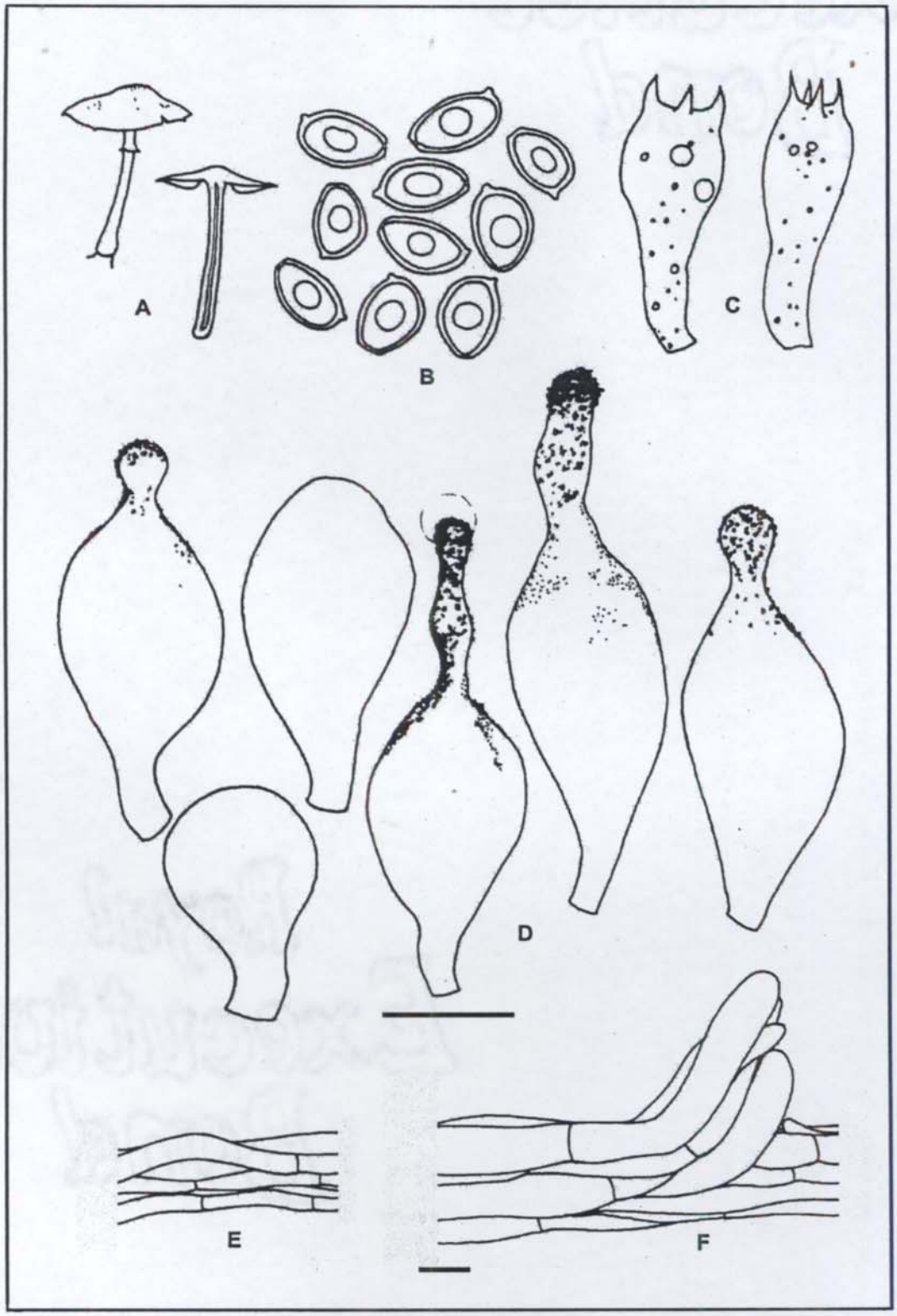


Figure 46. ' *Lepiota viridiflava*' **A.** Habit x 1 **B.** Spores **C.** Basidia **D.** Cheilocystidia **E.** Stipe covering **F.** Pileus covering. Bars = 10 µm.

***Leucoagaricus* species 4**

Fig. 47. A-F; Pl. 46.

Basidiomata medium-sized. **Pileus** 15-43 mm diam., initially campanulate with an umbo, becoming convex to broadly convex on maturity, distinctly umbonate at the disc; surface white, with concolorous or occasionally yellowish white (2A2), recurved, fibrillose squamules, striate towards margin; margin initially incurved, becoming straight, eroded. **Lamellae** free, whitish, crowded, up to 5 mm wide, with lamellulae in 2-3 tiers; edge finely fimbriate under a lens, concolorous with the sides. **Stipe** 25-86 × 2-5 mm, central, terete, almost equal but slightly expanded towards base (up to 6 mm), initially fistulose becoming hollow with age; surface whitish, turning pale yellow (4A3) on bruising, almost glabrous; base arising from a white mycelium. **Annulus** superior or central, membranous, simple, ascending, fixed. **Context** up to 1 mm thick, whitish, changing to pale yellow (4A3) on exposure. **Odour** not distinctive. **Spore-print** white.

Spores 5-6.5 × 3.5-4 (5.7 ± 0.44 × 4 ± 0.2) µm, Q = 1.3-1.7, Qm = 1.5, ellipsoid to ovoid or amygdaliform, without a germ-pore, hyaline, with refractive guttules, thick-walled (up to 1 µm), smooth, dextrinoid, metachromatic in cresyl blue, cyanophilous in cotton blue. **Basidia** 11-15 × 6-8 µm, short clavate, hyaline, bearing 4 short sterigmata up to 2 µm long. **Lamella-edge** sterile. **Cheilocystidia** crowded, 19-42 × 11.5-17 µm, narrowly clavate, clavate, cylindrical, ellipsoid, obovoid or rarely utriform,

thin-walled, hyaline. **Pleurocystidia** absent. **Lamellar trama** subregular; hyphae 2-30 µm wide, inflated, branched, hyaline, thin-walled, inamyloid. **Subhymenium** cellular. **Pileal trama** interwoven, composed of highly inflated, 3-40 µm wide, hyaline, thin-walled, inamyloid hyphae. **Pileal covering** a repent cutis of inflated, 2-25 µm wide, thin-walled hyaline hyphae with occasionally ascending terminal elements. **Stipe covering** a cutis of slightly inflated, thin- to slightly thick-walled, 3-34 µm wide, hyaline hyphae. Clamp-connections rarely present on hyphae of the pileal covering.

Habitat: On soil, among decaying leaf litter, solitary or scattered.

Known Distribution: Only from the type locality.

Collections examined — Malappuram District, Calicut University Campus: 3 June 2005, AK230; 6 June 2005, AK235.

This thin-fleshed species is distinct with a pure white pileal background covered with almost concolorous squamules, a fixed annulus, ellipsoid to amygdaliform spores without a germ-pore, short clavate basidia, and a cutis-type pileal covering. This species is considered as belonging to the genus *Leucoagaricus* because of the absence of distinct plicate/sulcate striations on the pileus and due to the lack of pseudoparaphyses in the hymenium. An already published matching species description could not be found to satisfactorily place the present collection. *Leucoagaricus hortensis*

(Murrill) Pegler (= *Chlorophyllum hortense* (Murrill) Vellinga), a white species differs on account of its larger fleshy basidiomata whose stipe context shows strong reddening reaction when bruised, two-spored basidia, larger spores, and a subhymeniform pileal covering with clavate terminal elements.

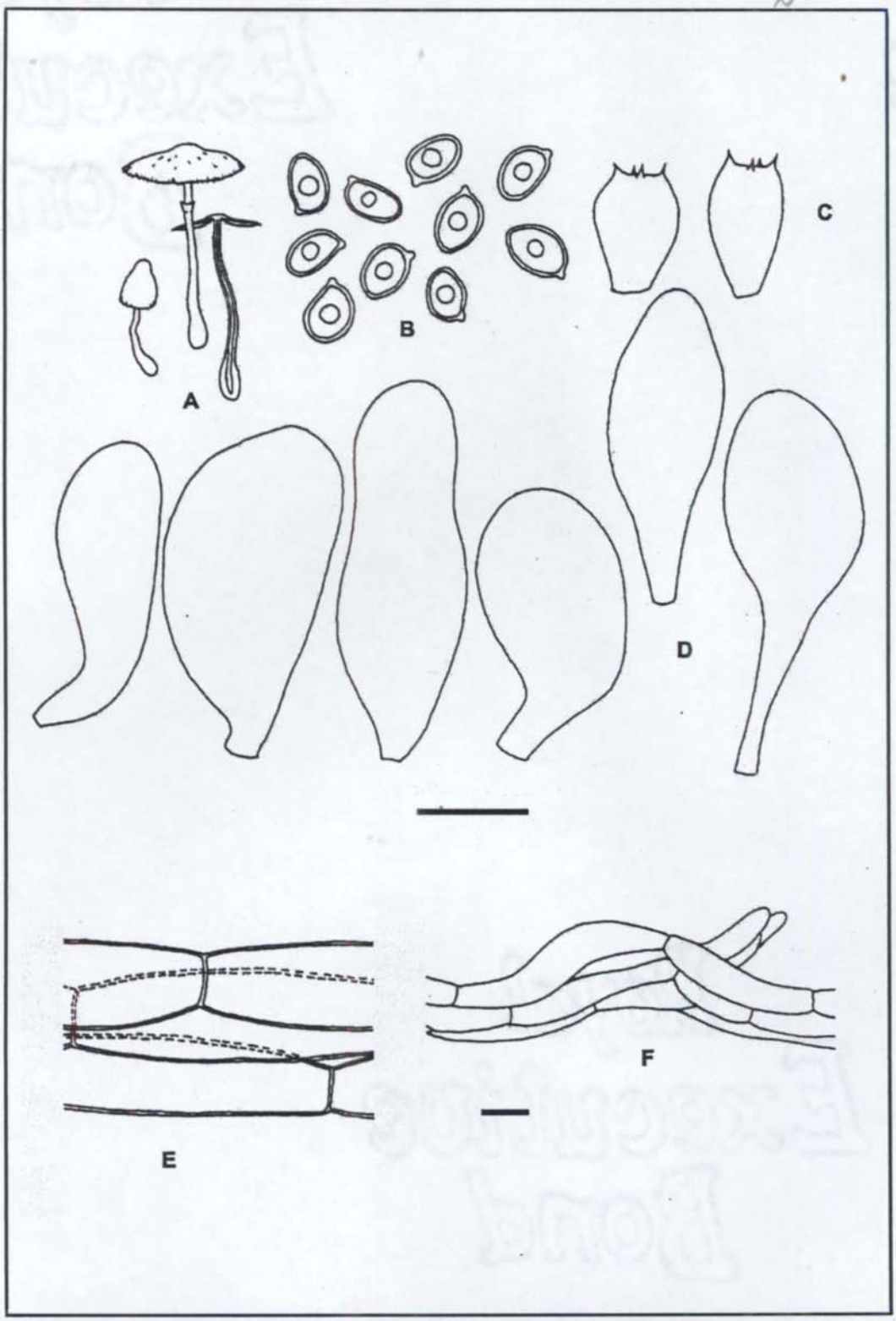


Figure 47. *Leucoagaricus* species 4 **A.** Habit x 1 **B.** Spores **C.** Basidia **D.** Cheilocystidia **E.** Stipe covering **F.** Pileus covering. Bars = 10 µm.

Plate 45. '*Lepiota viridiflava*' x 3.5

Plate 46. *Leucoagaricu* species 4 x 2.5

5.1.4.1.3 Section ***Leucoagaricus***

Pileus not brightly coloured, densely fibrillose or more or less scaly; context unchanging; spores without germ-pore.

Type species: *Leucoagaricus macrorhizus* (Locquin) Singer

***Leucoagaricus* species 2**

Fig. 48. A-F; Pl. 47.

Basidiomata small. **Pileus** 10-22 mm diam., ovoid when young, becoming convex to broadly convex and finally applanate, with an indistinct umbo; surface yellow (2A6), yellowish white (2A2) towards margin, with concolorous recurved squamules scattered except at the disc which remains smooth, sulcate-striate towards margin; cuticle peeling off as a layer at maturity or on ageing revealing the underlying context; margin initially incurved, becoming straight or upturned with age, entire to slightly crenate. **Lamellae** free, initially white, becoming yellowish white (2A2), close to crowded, up to 4 mm wide, with lamellulae in 2-3 tiers; edge finely fimbriate under a lens, concolorous with the sides. **Stipe** 14-30 × 1-3 mm (up to 6 mm wide at the base), central, terete, expanded towards the base, solid when young, becoming fistulose and finally hollow with age; surface whitish, fibrillose; base arising from a white mycelium. **Annulus** central, membranous, ascending, fixed. **Context** up to 1 mm thick, yellow (2A6). **Odour** not distinctive. **Spore-print** white.

Spores 4-7 × 2.5-3.5 (5.5 ± 0.8 × 3 ± 0.2) µm, Q = 1.6-2.3, Qm = 1.9, amygdaliform, hyaline, with refractive guttules, thick-walled, smooth, dextrinoid, weakly metachromatic in cresyl blue, cyanophilous in cotton blue. **Basidia** 11-23 × 5-8 µm, clavate, hyaline, with guttulate contents, bearing 4 sterigmata up to 3 µm long. **Lamella-edge** sterile. **Cheilocystidia** 20-39 × 6.5-12 µm, cylindrico-clavate to inflated clavate, rarely with 1-2 finger-like apical protrusions, hyaline, thin-walled. **Pleurocystidia** absent. **Lamellar trama** subregular; hyphae 2-18 µm wide, inflated, septate, hyaline, thin-walled, inamyloid. **Subhymenium** cellular. **Pileal trama** interwoven; hyphae 2-25 µm wide, inflated, hyaline, thin-walled, inamyloid. **Pileal covering** a cutis of loosely attached 3-25 µm wide, inflated hyphae, thin-walled, hyaline to pale yellow, occasionally disrupted by ascending, terminal elements; terminal elements 16-53 × 8-22 µm, cylindrical, thin-walled, with pale yellow plasmatic pigment. **Stipe covering** a cutis of 2-10 µm wide, hyaline, thin-walled hyphae with cylindrical or moniliform, at times branched elements often arising as lateral branches; terminal elements 21-90 × 4-9 µm, hyaline, thin-walled. All hypahe lack clamp-connections.

Habitat: On soil and on decaying leaf litter, solitary.

Known Distribution: Only from the type locality.

Collections examined — Malappuram District, Calicut University Campus: 4 October 2004, AK116; 5 October 2004, AK123; 15 October 2004, AK138; 26 October 2004, AK150; 1 November 2004, AK116a;

This species is characterized by a yellowish pileus with striations towards the margin, amygdaliform spores that are dextrinoid and weakly metachromatic in cresyl blue, cylindrico-clavate to inflated clavate cheilocystidia rarely having apical projections, cutis-type pileal covering disrupted by ascending cylindrical terminal elements, stipitipellis with branched, cylindrical or distinctly moniliform elements and by the absence of clamp-connections.

Although this species has weakly metachromatic spores, a combination of characters such as total absence of clamp-connections and presence of cheilocystidia with apical extensions justify its placement in *Leucoagaricus* rather than in *Lepiota sensu stricto*. A consideration under the genus *Leucocoprinus* is also ruled out because of the lack of pseudoparaphyses in the hymenium. These collections from Kerala represent a hitherto undescribed species, as no identical species descriptions have been found even after a thorough literature search.

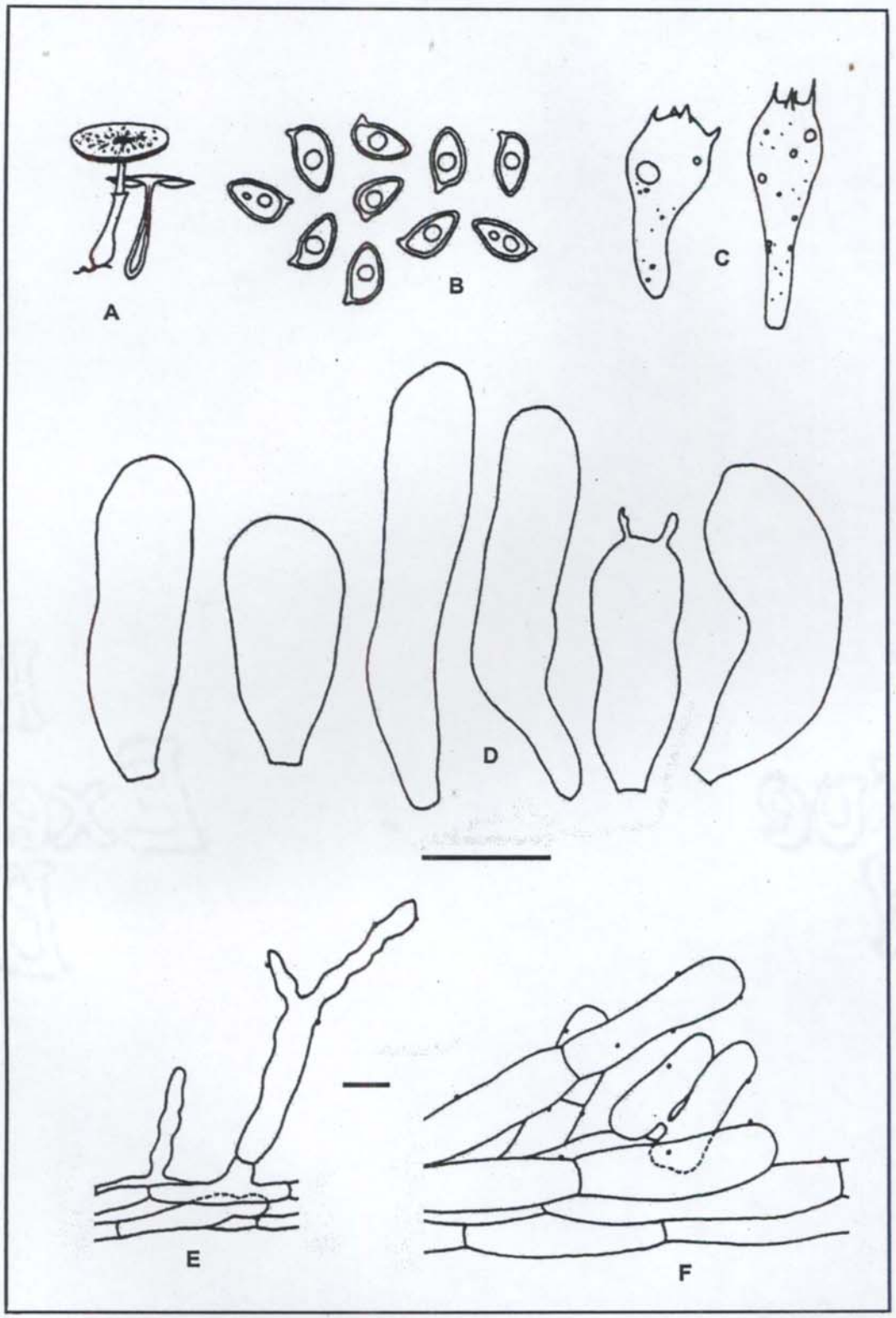


Figure 48. *Leucoagaricus* species 2 **A.** Habit x 1 **B.** Spores **C.** Basidia **D.** Cheilocystidia **E.** Stipe covering **F.** Pileus covering. Bars = 10 µm.

***Leucoagaricus* species 1**

Fig. 49. A-F; Pl. 48.

Basidiomata small. **Pileus** 10-15 mm diam., subglobose when young, becoming convex to broadly convex and finally applanate, with an indistinct umbo; surface white, with minute, recurved, pale yellow (3A3) to orange white (5A2) or brownish orange (5C4) squamules scattered throughout and concentrated towards the disc, canescent, distinctly sulcate-striate towards margin; margin initially incurved, later straight, crenate. **Lamellae** free, white, close to moderately crowded, up to 2 mm wide, with lamellulae in 2-3 tiers; edge finely fimbriate under a lens, concolorous with the sides. **Stipe** 15-34 x 1-2 mm (up to 5 mm wide at the base), central, terete, almost equal above the annulus, expanding towards base, initially solid, becoming fistulose; surface white, fibrillose-villose; base arising from white mycelial cords. **Annulus** central or superior, membranous, descending, fixed. **Context** less than 1 mm thick, white. **Odour** not distinctive. **Spore-print** white.

Spores 6-11 x 5-7.5 (8.5 ± 1 × 6 ± 0.09) µm, Q = 1.1-1.8, Qm = 1.5, ellipsoid, broadly ellipsoid, ovoid, or subglobose, without a germ-pore, hyaline, with refractive guttules, somewhat thick-walled, smooth, dextrinoid, metachromatic in cresyl blue, cyanophilous in cotton blue. **Basidia** 19-40 x 10-15 µm, clavate to broadly clavate, with guttulate contents, bearing 4 sterigmata up to 5 µm long. **Lamella-edge** sterile with crowded

cheilocystidia. **Cheilocystidia** 17-57 x 6-26 µm, versiform: obovoid, oblong, ellipsoid, inflated-clavate, utriform or rarely cylindrical, hyaline, thin-walled. **Pleurocystidia** absent. **Lamellar trama** subregular; hyphae 2-30 µm wide, inflated, septate, hyaline, thin-walled, inamyloid. **Subhymenium** cellular. **Pileal trama** interwoven; hyphae 3-23 µm wide, inflated, hyaline, thin-walled, inamyloid. **Pileal covering** a cutis of 5-12 µm wide, filamentous hyphae disrupted by ascending or erect patches of hyphae with cylindrical or clavate terminal elements; terminal elements, 22-70 x 6-20 µm, hyaline to pale yellow, thin-walled. **Stipe covering** a disrupted cutis of 2-20 µm wide, hyaline to pale yellow, thin-walled, branched hyphae with cylindrico-clavate terminal elements. All hypahe lack clamp-connections.

Habitat: On soil and among decaying leaf litter, solitary or scattered.

Known Distribution: Only from the type locality.

Collections examined — Calicut District, Puthiyangadi: 29 October 2003, AK10; 30 September 2004, AK111; 14 October 2004, AK111a; Malappuram District, Calicut University Campus: 26 October 2004, AK153; 2 November 2004, AK153a; Nilambur: 13 September 2004, AK97; Wayanad District, Muthanga: 2 June 2005, AK 225.

Subglobose to broadly ellipsoid spores that are metacromatic in cresyl blue, obovoid, inflated-clavate, clavate or utriform cheilocystidia, and a pileal

covering that is basically a cutis disrupted by ascending patches of loose hyphae with cylindrical, ellipsoid or clavate terminal elements are the distinguishing characters of this species. Spores that are metachromatic in cresyl blue and the absence of pseudoparaphyses keep the species inside the genus *Leucoagaricus*. But the characters observed in the present collection do not identify it with any of the species described so far.

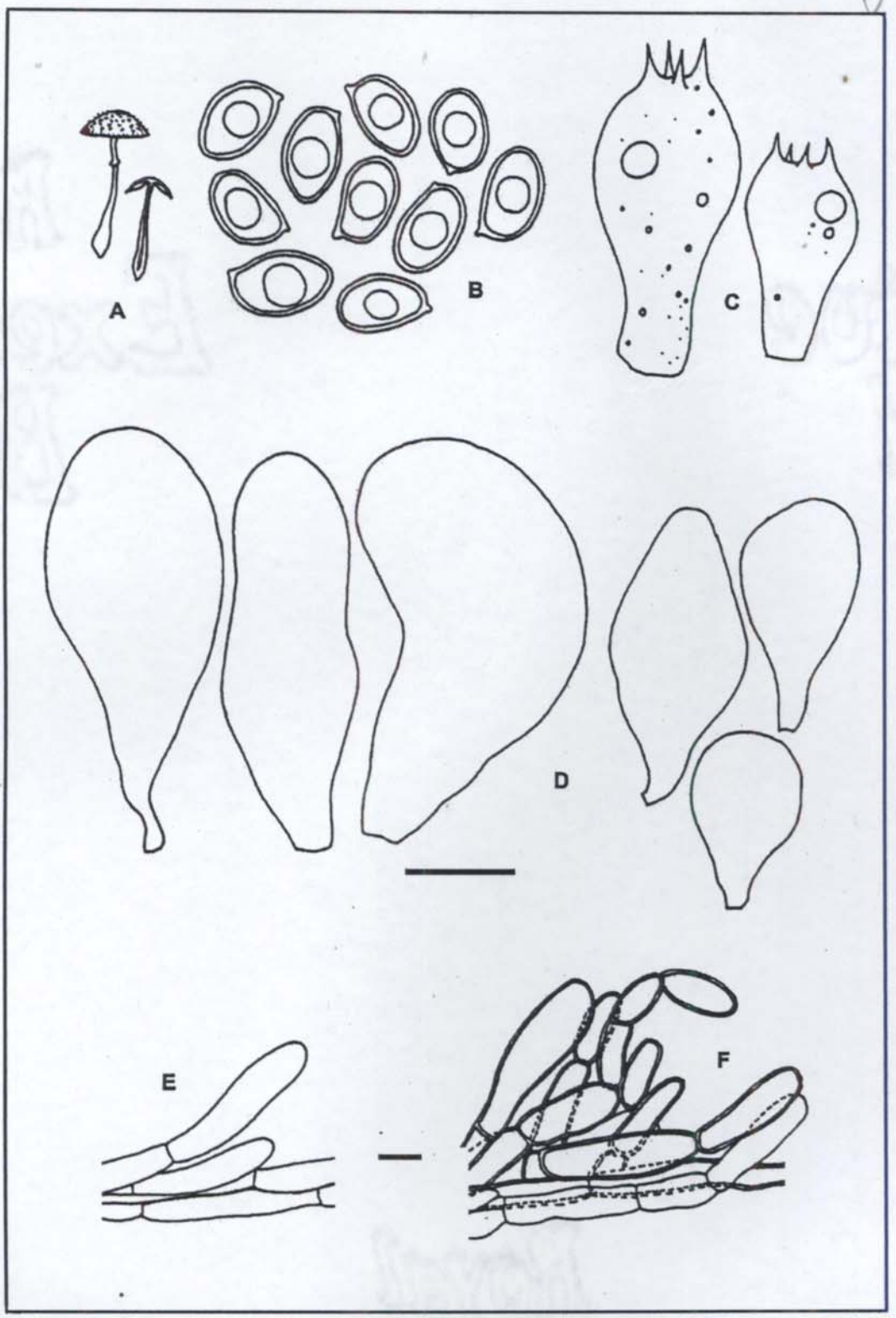


Figure 49. *Leucoagaricus* species 1 **A.** Habit x 1 **B.** Spores **C.** Basidia **D.** Cheilocystidia **E.** Stipe covering **F.** Pileus covering. Bars = 10 µm.

Plate 47. *Leucoagaricus* species 2 x 3.5

Plate 48. *Leucoagaricus* species 1 x 6

5.1.5 *Macrolepiota* Singer

Macrolepiota Singer in Papers from the Michigan Academy of Science, Arts and letters 32: 141 ('1946') (1948)

Basidiomata large, fleshy; pileus with scattered squamules ; lamellae free, mostly with a concolorous edge; stipe central, almost equal, bulbous at the base, fibrillose or squamulose; annulus complex, initially fixed, becoming movable with age; context in many species changing colour on exposure, on bruising or with age; spore-print pure white; spores large, dextrinoid, metachromatic in cresyl blue, with a germ-pore, covered with hyaline exudates, thick-walled; cheilocystidia present; pleurocystidia absent; lamellar trama subregular, of inflated hyphae; pileal covering with trichodermial patches of ascending or erect elements; stipe covering with trichodermial patches of ascending or erect elements; clamp-connections present.

Type species: *Macrolepiota procera* (Scopoli) Singer

Only a single species of *Macrolepiota* has been collected from Kerala.

Macrolepiota dolichaula (Berkeley & Broome) Pegler & Rayner in Kew Bulletin 23: 365 (1969)

Leucocoprinus dolichaulus (Berkeley & Broome) Patouillard in Bulletin trimestriel de la Société mycologique de France 29: 215 (1913)

Leucocoprinus dolichaulus (Berkeley & Broome) Boedijn in Sydowia 5: 221 (1951)

Lepiota dolichaula (Berkeley & Broome) Saccardo in Sylloge Fungorum 5: 32 (1887)

Agaricus dolichaulus Berkeley & Broome in Transactions of the Linnean Society, Botany 27: 150 (1870)

- *Agaricus beckleri* (Berkeley) Saccardo in Journal of the Linnean Society 13: 156 (1872)

Lepiota beckleri (Berkeley) Saccardo in Sylloge Fungorum 5: 56 (1887)

- *Lepiota stenophylla* (Cooke & Massee) Saccardo in Sylloge Fungorum 9: 4 (1891)

Fig. 50. A-F; Pl. 49.

Basidiomata large and fleshy. **Pileus** 65-130 mm diam., subglobose to convex when young, becoming broadly convex to applanate with a distinct umbo at the disc; surface white with numerous, scattered, minute, brownish orange (6C4) to light brown (6D4, 6D5) squamules which are sparser towards the margin and more concentrated towards the disc, finely pruinose at the disc, fibrillose; margin initially incurved, later straight, becoming upturned with age, entire to appendiculate. **Lamellae** free, white, turning dull white with age, crowded, up to 7 mm wide, with lamellulae in 3-4 tiers; edge finely fimbriate under a lens, concolorous with the sides. **Stipe** 160-250 × 10-12 mm (up to 25 mm wide at the base), central, terete, almost equal, slightly expanded or bulbous at the base, initially fistulose becoming hollow; surface whitish, turning brown (6E8) on bruising, fibrillose; base arising from a white mycelium. **Annulus** superior, membranous, descending, bilipped, rather thick, initially fixed, movable with age. **Context** less than 5 mm thick, white. **Odour** mild, that of oven-fresh bread. **Spore-print** white.

Spores 11-14 × 8-10 (12.65 ± 0.98 × 9 ± 0.2) µm, Q = 1.3-1.6, Qm = 3.25, ovoid to ellipsoid, hyaline, with a germ-pore up to 1 µm broad or

inconspicuous in some, covered by fine hyaline cap, with refractive guttules, thick-walled (up to 1.5 µm), smooth, dextrinoid, metachromatic in cresyl blue, cyanophilous in cotton blue. **Basidia** 34-46 × 13-15 µm, clavate, with guttulate contents, hyaline, bearing 4 sterigmata up to 5 µm long. **Lamella-edge** sterile. **Cheilocystidia** 14-38 × 8-15 µm, clavate to broadly clavate or rarely utriform, hyaline, thin-walled. **Pleurocystidia** not observed. **Lamellar trama** subregular; hyphae 2-10 µm wide, slightly inflated, hyaline, thin-walled, inamyloid. **Subhymenium** cellular. **Pileal trama** interwoven; hyphae 2-10 µm wide, cylindric, septate, hyaline, thin-walled, branched, inamyloid. **Pileal covering** a highly disrupted cutis with ascending or erect hyphae in agglutinated patches at the disc and scales; hyphae closely septate, compactly arranged, filamentous, 5-12 µm wide, thin-walled, hyaline; trichodermial patches composed of erect, branched chains of subglobose, ellipsoid or barrel shaped, 7-26 × 6-10 µm, slightly thick-walled, pale brown to brown elements. **Stipe covering** basically a cutis of 6-10 µm wide, cylindrical, hyaline, thin-walled hyphae, frequently highly disrupted by trichodermial patches of ascending or erect chains of short cylindrical, ellipsoid or almost isodiammetric elements, 12-35 × 7-16 µm, hyaline and thin-walled. Clamp-connections present in the lamellar tramal hyphae and at the basidial base.

Habitat: On soil in grasslands, solitary or scattered.

Known Distribution: AFRICA, Australia, Brazil, India, Mexico, Sri Lanka

Collections examined — Malappuram District, Calicut University Campus: 8 October 2004, AK129; 11 October 2004, AK129a; 26 October 2004, AK146; 26 October 2004, AK147; 2 November 2004, AK146a; 17 November 2004, AK205; 20 September 2006, AK440; Thiruvananthapuram District, Perayam: 3 August 2006, AK426.

This species is characterized by large and fleshy basidiomata, minute squamules, long stipe usually about double the pileus diameter, large spores with hyaline germ-pore covering, trichodermial pileal covering, a stipe covering with trichodermial patches, and clamp-connections. The hyaline exudate covering the germ-pore in spores of the Kerala collections were rather inconspicuous. Characters of the present collections very well agree with those of the species from East Africa and Sri Lanka (Pegler 1986). The species has already been reported from India by Manjula (1983) and Natarajan & Raman (1983).

This species belongs to *Macrolepiota* section *Macrolepiota* and constitutes the only species belonging to *Macrolepiota sensu* Vellinga (see review) so far collected from Kerala. Another taxon, *Macrolepiota rachodes* variety *brunneum* collected from Kerala during this study has been transferred to *Chlorophyllum sensu* Vellinga as amended concepts (Vellinga 2002; Vellinga et al. 2003) of these two genera, supported by morphological and molecular evidences are followed in this study.

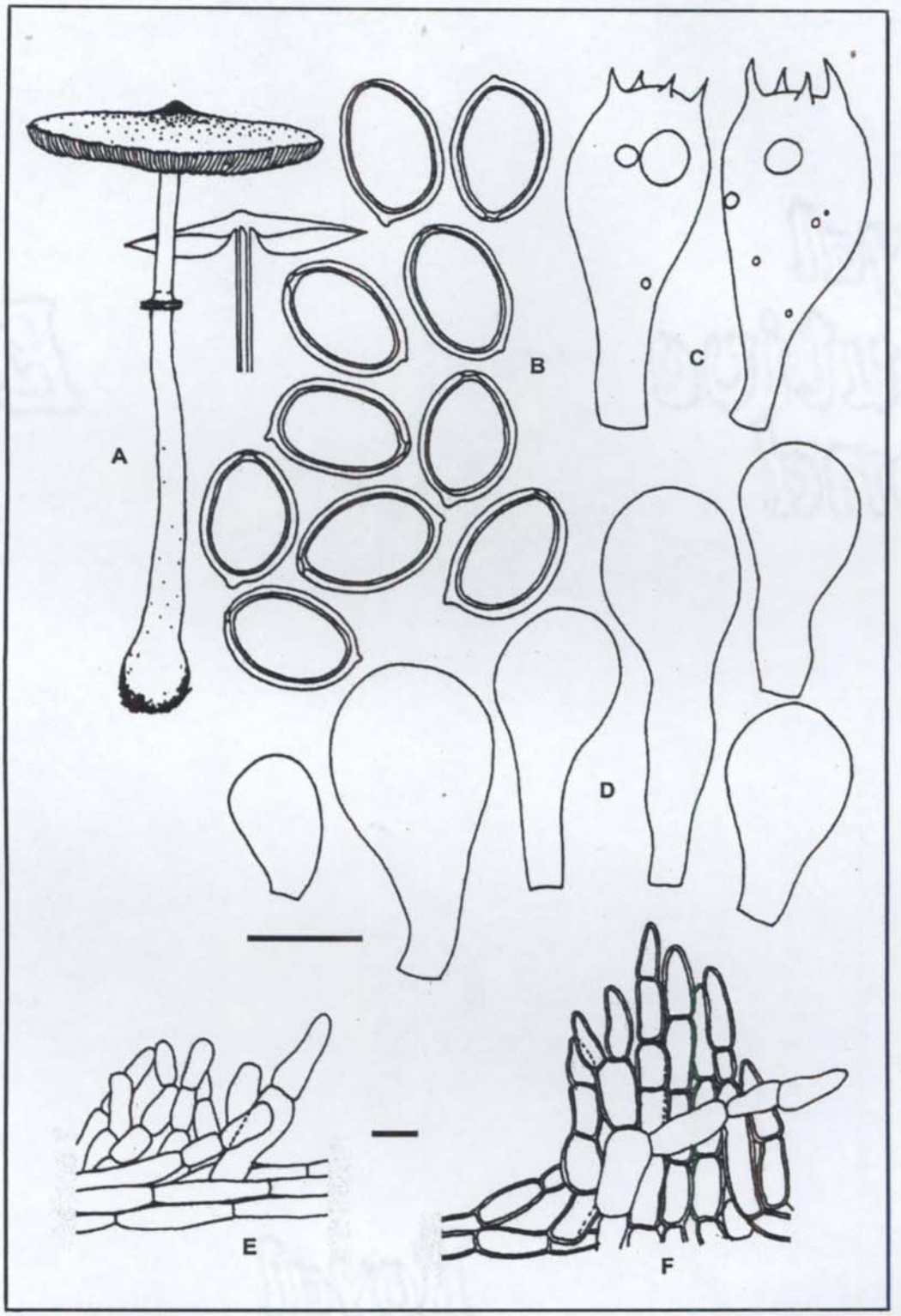


Figure 50. *Macrolepiota dolichaula* **A.** Habit x 1 **B.** Spores **C.** Basidia **D.** Cheilocystidia **E.** Stipe covering **F.** Pileus covering. Bars = 10 µm.

5.1.6 *Chlorophyllum* Massee

Chlorophyllum Massee in Kew Bulletin 1898: 136 (1898), *non* *Chlorophyllum* Murrill (1910)

Macrolepiota section *Chlorophyllum* (Massee) Moreno *et al.* in Mycotaxon 55: 469 (1995).

Basidiomata large, fleshy; pileus with scattered squamules ; lamellae free, white, yellowish white, greenish, mostly with a concolorous edge; stipe central, almost equal, bulbous at the base, smooth, fibrillose; annulus complex, initially fixed becoming movable with age; context in many species changing colour on exposure, bruising with age; spore-print white or greenish; spores large, dextrinoid, metachromatic in cresyl blue, germ-pore present; thick-walled; cheilocystidia present; pleurocystidia absent; lamellar trama subregular, of inflated hyphae; pileal covering highly trichodermial or a hymeniform of ascending or erect elements; stipe covering a cutis; clamp-connections rare.

Type species: *Chlorophyllum esculentum* Massee

5.1.6.1 KEY TO THE *CHLOROPHYLLUM* SPECIES OF KERALA

1. Spore-print greenish; lamellae greyish green; cheilocystidia inflated clavate ..... ***Chlorophyllum molybdites***
1. Spore-print white; lamellae white to yellowish white; cheilocystidia not inflated **2**
2. Spores with a broad germ-pore; cheilocystidia clavate with a long pedicellate base; clamp-connections present ..... ***Chlorophyllum brunneum***

2. Spores lacking germ-pore (rarely rudimentary); cheilocystidia clavate, flexuose or utriform without a distinctly pedicellate base; clamp-connections absent..... **3**
3. Pileus whitish, striate towards margin; stipe with a slightly bulbous base; basidia predominantly 2-spored..... ***Chlorophyllum hortense***
3. Pileus greyish brown, non-striate; stipe base marginately bulbous; basidia predominantly 4-spored..... ***Chlorophyllum abruptibulbum***

Chlorophyllum molybdites (Meyer) Massee in Kew Bulletin 1898: 136 (1898)

Agaricus molybdites Meyer in Systema mycologicum 1: 308 (1821)

Agaricus morganii Peck. in Botanical Gazette in 4: 137 (1879)

Lepiota molybdites (Meyer) Saccardo in Sylloge Fungorum 5: 30 (1887)

Lepiota morganii (Peck) Saccardo in Sylloge Fungorum 5: 30 (1887)

Pholiota glaziovii (Berkeley) Saccardo in Sylloge Fungorum 5: 751 (1887)

Mastocephalus molybdites (Meyer) Kuntze in Revisium Generum Plantarum 2: 860 (1891)

Mastocephalus morganii (Peck) Kuntze in Revisium Generum Plantarum 2: 860 (1891)

Lepiota ochrospora Cooke & Massee in Grevillea 21: 73 (1893)

Chlorophyllum morganii (Peck) Massee in Kew Bulletin 1898: 136 (1898)

Chlorophyllum esculentum Massee in Kew Bulletin 1898: 136 (1898)

Agaricus quadelupensis Patouillard in Bulletin de la Sociéte mycologique de France 15: 197 (1899)

Annularia camporum Spegazzini in Anales del Museo nacional de historia natural de Buenos Aires 6: 117 (1899)

Lepiota esculenta (Massee) Saccardo & Sydow in Sylloge Fungorum 16: 2 (1901)

Leucocoprinus molybdites (Meyer) Patouillard in Bulletin de la Sociéte mycologique de France 29: 215 (1913)

Lepiota camporum (Spegazzini) Spegazzini in Boletin de la Academia nacional de ciencias en Córdoba 29: 114 (1926)

Agaricus congolensis Beeli in Bulletin de la Société Royale de Botanique de Belgique 61: 92 (1928)

Chlorophyllum molybdites variety *congolense* (Beeli) Heinemann in Flore Iconographique des champignons du Congo, 16: 323 (1967)

Fig. 51. A-F; Pl. 50.

Basidiomata large and fleshy. **Pileus** 100-125 mm diam., initially convex, becoming broadly convex and finally applanate with an indistinct umbo; surface whitish with a greyish orange (5B4) to brown (6D6) pellicle that disrupts to form plate-like squamules towards the centre, with white granular and punctuate squamules towards the margin; finely striate at margin; margin incurved when young, becoming straight on maturity, entire. **Lamellae** free, initially white, turning pale yellow (2A3) and finally greyish green (1C4), crowded, up to 12 mm wide, with lamellulae in 4 tiers; edge finely fimbriate under a lens, concolorous with the sides. **Stipe** 135-160 × 13-14 mm (up to 27 mm wide at the base), central, terete, initially fistulose, becoming hollow, almost equal with a bulbous base; surface initially white, turning pastel yellow (2A4) to light yellow (3A5) and turning orange white (5A2) to rust brown (6E8) on bruising, glabrous; base arising from a white mycelium. **Annulus** large and firm, superior, membranous, double, movable,

smooth above, furfuraceous below. **Context** up to 10 mm thick, white, turning light yellow (3A5) with age and turning orange white (5A2) to reddish brown (8D7) on bruising. **Odour** not distinctive but faintly unpleasant in old specimens. **Spore-print** initially greyish yellow (1B4) to greyish green (1C4), turning pale yellow (3A3) to cream (4A3) on drying.

Spores 7-12.5 × 6-8 (9.9 ± 1.5 × 7.4 ± 0.75) µm, Q = 1-1.5, Qm = 1.34, ovoid in top view, amygdaliform in side view, with a somewhat truncated germ-pore, hyaline to pale green, with refractive guttules and a thick (up to 1.5 µm) complex wall, smooth, dextrinoid, indistinctly metachromatic in cresyl blue, cyanophilous in cotton blue. **Basidia** 25-37 × 12-14 µm, clavate, with guttulate contents, bearing 4 sterigmata up to 5 µm long. **Lamella-edge** sterile. **Cheilocystidia** 15-53 × 8-22 µm, inflated-clavate, hyaline, thin-walled. **Pleurocystidia** absent. **Lamellar trama** regular to subregular, of 5-20 µm wide, inflated, thin-walled, hyaline, inamyloid hyphae. **Subhymenium** cellular. **Pileal trama** interwoven; composed of 2-20 µm wide, inflated, hyaline, septate, thin-walled, inamyloid hyphae with obtuse tips. **Pileal covering** towards margin a cutis disrupted by ascending or erect agglutinated hyphal bundles; hyphae, 2-20 µm wide, inflated, septate, with cylindrical terminal elements with obtuse tips; the pellicle at the disc composed of a broad layer of compactly arranged, somewhat upright hyphae often covered by a narrow layer of repent or appressed hyphae; hyphae 2-5 µm wide, thin-walled, with yellow to pale brown plasmatic pigment. **Stipe covering** a cutis of 2-15 µm wide, cylindrical, hyaline,

septate, thick-walled hyphae. Clamp-connections present, but extremely rare, observed in pileal tramal hyphae.

Habitat: On soil in grasslands and along roadsides, solitary or scattered.

Known Distribution: AFRICA, ASIA, EUROPE, New Zealand, NORTH AMERICA, SOUTH AMERICA. The species is known to have an extensive distribution in both tropical and temperate regions, but is mainly pantropical according to Guzmán & Guzmán-Dávalos (1992).

Collections examined — Malappuram District, Calicut University Campus: 10 October 2003, AK4; 24 May 2004, AK30; 16 June 2004, AK56; Olipramkadavu: 4 June 2005, AK232; Calicut District, Mankave: 21 May 2004, AK29; Devagiri: 9 July 2004, AK66; Kodenchery: 22 July 2004, AK74; Nallalam: 28 June 2006, AK403.

This species has already been listed from Kerala (Florence 2004). The description of the present collections agrees with the known accounts on the species from different parts of the world (e.g. Gosh *et al.* 1976; Pegler 1977, 1986; Wasser 1993; Vellinga 2001e). This is a very common agaric often encounterd along roadsides and lawns in Kerala that fruits rapidly with the onset of monsoon.

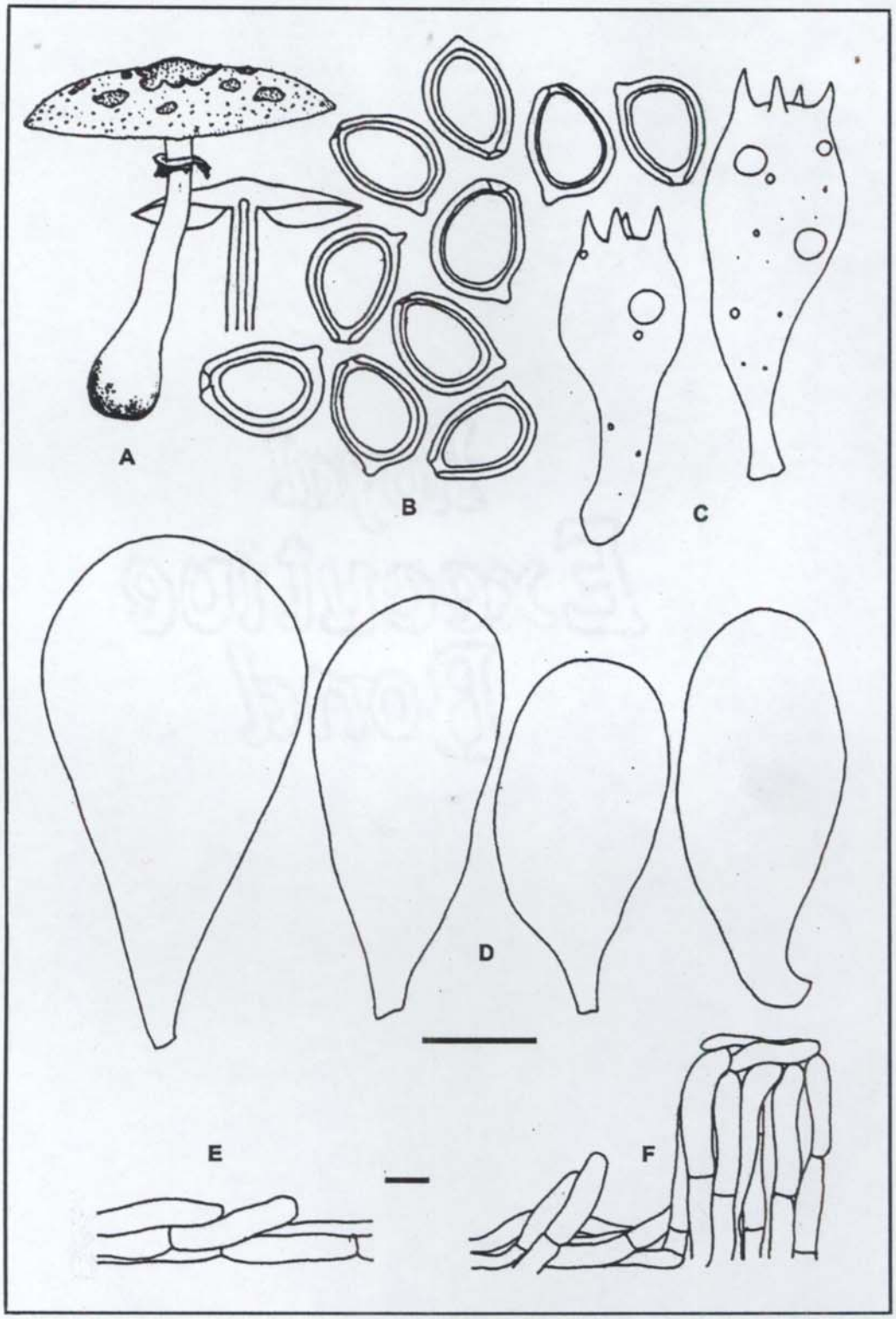


Figure 51. *Chlorophyllum molybdites* **A.** Habit x 1 **B.** Spores **C.** Basidia **D.** Cheilocystidia **E.** Stipe covering **F.** Pileus covering. Bars = 10 µm.

Plate 49. *Macrolepiota dolichaula* x 1

Plate 50. *Chlorophyllum molybdites* x 1

Chlorophyllum brunneum (Farlow & Burt) Vellinga, Mycotaxon 83: 416 (2002)

Lepiota brunnea Farlow & Burt in Icones farlowianae: 8, pl 6, (1929)

Macrolepiota rachodes var. *brunnea* (Farlow & Burt) Candusso in Candusso & Lanzoni in *Lepiota* s. l., Fungi Europei 4:535 (1990)

Macrolepiota brunnea (Farlow & Burt) Wasser in Tribes *Cystodermatae* Sing. and *Leucocoprineae* Sing. of the CIS and Baltic States (Libri Botanici 9): 82 (1993)

Fig. 52. A-F; Pl. 51.

Basidiomata large and fleshy. **Pileus** 35-130 mm diam., globose to subglobose when young, becoming somewhat campanulate to broadly convex and finally applanate with age, broadly umbonate at the disc; surface whitish with dark brown (9F4, 9F5) large appressed squamules in broken concentric circles; squamules covering the disc and giving a smooth appearance; margin initially incurved, later straight, entire. **Lamellae** free, initially white, turning yellowish white (3A2), crowded, up to 14 mm wide, with lamellulae in 5-6 tiers; edge finely fimbriate under a lens, concolorous with the sides. **Stipe** 90-120 × 11-15 mm (up to 29 mm wide at the base), central, terete, almost equal, fistulose, with a marginately bulbous base; surface whitish, turning dark brown (9F4) on bruising or on touch, fibrillose; base arising from thick white mycelial cords. **Annulus** superior, membranous, ascending, fixed, with dense dark brown (9F4) appressed squamules on the under side of a highly eroded rim. **Context** up to 10 mm thick, whitish changing to brown (7E8) and finally dark brown (9F4) on exposure. **Odour** not distinctive. **Spore-print** white.

Spores 7.5-10 × 5-6.5 (8 ± 0.94 × 5.9 ± 0.31) µm, Q = 1.25-1.7, Qm = 1.5, ellipsoid, broadly ellipsoid, or rarely ovoid, hyaline, with a germ-pore up to 1 µm broad, with large refractive guttules, thick-walled (up to 1 µm), smooth, dextrinoid, metachromatic in cresyl blue, cyanophilous in cotton blue. **Basidia** 23-32 × 10-11 µm, cylindrico-clavate to clavate, with guttulate contents, hyaline, with 4 sterigmata up to 3 µm long. **Lamella-edge** sterile. **Cheilocystidia** crowded, 19-75 × 6-13 µm, clavate with a long pedicellate base, rarely obovoid, occasionally septate, hyaline, thin-walled. **Pleurocystidia** absent. **Lamellar trama** regular; hyphae 2-7 µm wide, filamentous, hyaline, thin-walled, inamyloid. **Subhymenium** cellular. **Pileal trama** interwoven; hyphae 3-20 µm wide, slightly inflated, hyaline, thin-walled, inamyloid. **Pileal covering** a hymeniderm at the centre and at the scales, with erect, flexuose to clavate terminal elements, 16-67 × 5-11 µm, thin-walled and with dark brown plasmatic pigments; hyphae irregular, intertwined and increasingly prostrate towards the margin. **Stipe covering** a cutis; hyphae 3-9 µm wide, hyaline to pale grey, thin-walled. Clamp-connections present on hyphae of all parts, including the base of basidia and cystidia.

Habitat: On humus rich soil, solitary or scattered.

Known Distribution: ASIA, AFRICA, EUROPE, NORTH AMERICA, SOUTH AMERICA and AUSTRALIA.

Collections examined — Calicut District, Ramanattukara: 15 April 2005, AK215; 11 June 2005, AK256; Mankave: 16 June 2005, AK270.

This species seems to have characters of the taxon widely recognized as *Macrolepiota rachodes* (Vittadini) Singer. *M. rachodes* is a cosmopolitan species with several closely related taxa forming a highly disputed complex (Vellinga 2003b). The Kerala collections fit in well with the descriptions given by Gosh & Pathak (1965), Pegler (1977) and Wasser (1993), although Wasser gave a slighltly larger spore dimensions (9-12 × 6-7 µm) for his material. The present description agrees with that given by De Kok & Vellinga (1998) but they mention an annulus with a double crown. Vellinga (2001d), described *M. rachodes*, with larger spores and as possessing a double crowned annulus. Taking into account the presence of a simple annulus and following Bon (1996), the present collections could be identified as *Macrolepiota rachodes* variety *brunnea* (Farlow & Burt) Candusso. Wasser (1993: 82) provided an excerpt of the original description of the species (*L. brunnea*) with which the present account agrees well except for the slightly larger spores in the former. Following Vellinga (2002, 2003b, 2003c) this taxon could be currently identified as *Chlorophyllum brunneum* characterized by medium-sized basidiocarps, a simple annulus, an abruptly, often marginate, bulbous stipe base, often truncate spores, predominantly clavate (not sphaeropedunculate) cheilocystidia and clamp-connections at the base of cystidia and basidia, features by which it differs strictly from *Chlorophyllum rachodes* (Vittadini) Vellinga (= *M. rachodes*). This species is

accepted as belonging to *Chlorophyllum sensu* Vellinga 2002) in this study as this placement is found supported by morphological and molecular data (Vellinga 2003c, 2004a).

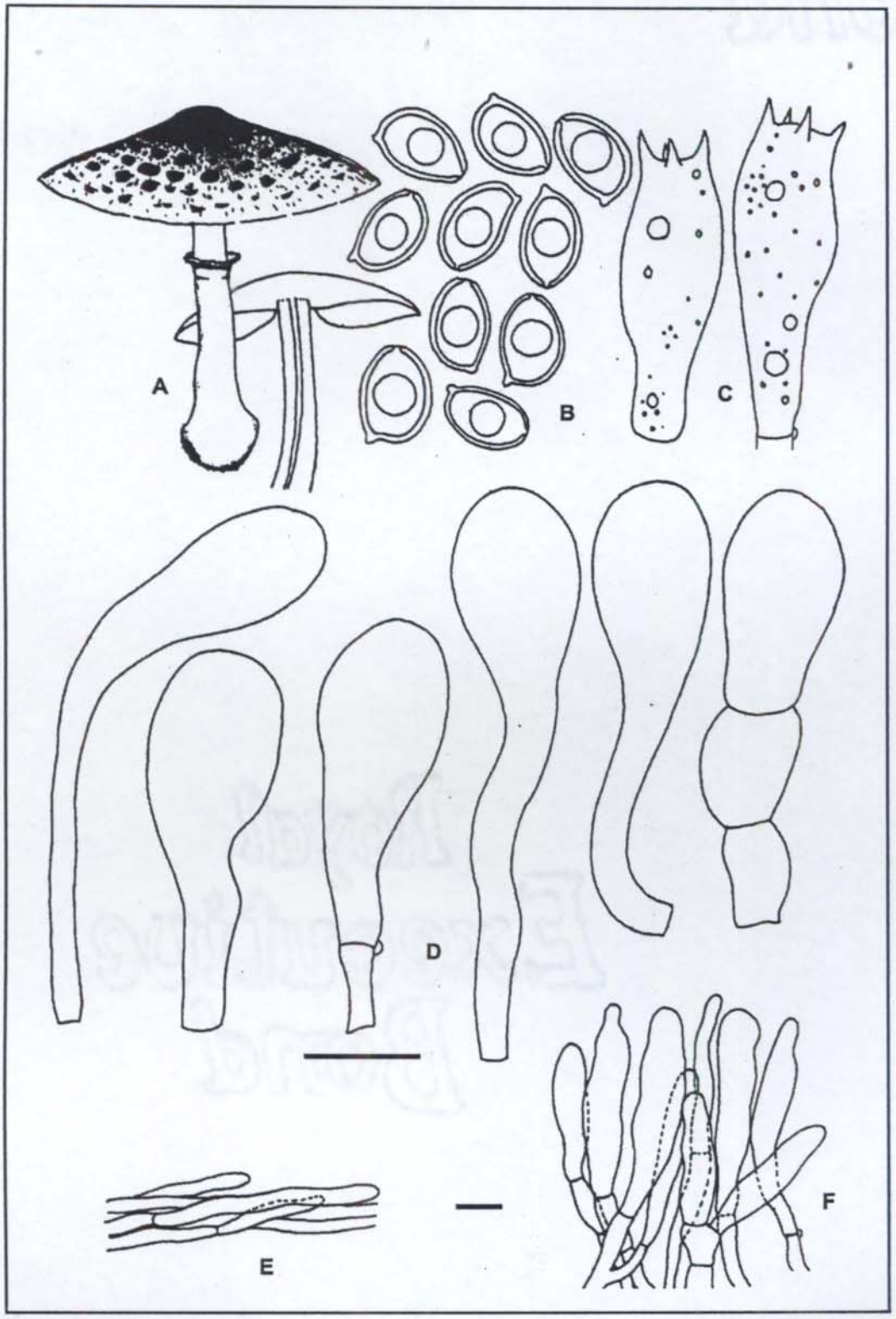


Figure 52. *Chlorophyllum brunneum* **A.** Habit x 1 **B.** Spores **C.** Basidia **D.** Cheilocystidia **E.** Stipe covering **F.** Pileus covering. Bars = 10 µm.

Chlorophyllum hortense (Murrill) Vellinga in Mycotaxon 83: 416 (2002)

Lepiota hortensis Murrill in North American Flora 10 (1): 59 (1914)

Lepiota humei Murrill in Lloydia 6: 220 (1943)

Lepiota mammillata Murrill in Lloydia 6: 220 (1943)

Lepiota subfulvidisca Murrill in Lloydia 6: 221 (1943)

Lepiota alborubescens Hongo in Memoirs of the Faculty of Liberal Arts and Education, Shiga University, Natural Science 12: 40 (1962)

Leucoagaricus bisporus Heinemann in Bulletin du Jardin Botanique National de Belgique 43: 8 (1973)

Leucoagaricus hortensis (Murrill) Pegler in Kew Bulletin Additional Series 9: 414-415 (1983)

Macrolepiota alborubescens (Hongo) Hongo in Transactions of the Mycological Society of Japan 27: 107 (1986)

Fig. 53. A-F; Pl. 52.

Basidiomata medium-sized to somewhat large. **Pileus** 52-81 mm diam., subglobose to parabolic when young, becoming convex to broadly convex and finally applanate, broadly umbonate at the disc; surface whitish with appressed greyish orange (5B3) scales scattered throughout but concentrated towards centre and completely covering the disc, finely striate towards margin; margin initially incurved, soon becoming straight, crenate to slightly eroded. **Lamellae** free, white, crowded, up to 8 mm wide, with lamellulae in 4-5 tiers; edge finely fimbriate under a lens, concolorous with the sides. **Stipe** 50-60 × 2-4 mm, central, terete, equal, with a slightly bulbous base, initially solid becoming fistulose with age; surface whitish, turning brown (7F5) with a vinaceous tinge on bruising, longitudinally

fibrillose; base arising from a white mycelium. **Annulus** superior, membranous, simple, fixed, ascending. **Context** up to 2 mm thick, whitish. **Odour** not distinctive. **Spore-print** white.

Spores 7-11 × 4-6 (8.6 ± 0.94 × 6 ± 0.63) µm, Q = 1.3-1.8, Qm = 1.5, broadly ellipsoid, ellipsoid, or rarely amygdaliform, without a germ-pore, hyaline, with refractive guttules, thick-walled (up to 1 µm), smooth, dextrinoid, metachromatic in cresyl blue, cyanophilous in cotton blue. **Basidia** 17-25 × 8-9 µm, clavate, thin-walled, hyaline, bearing 2 sterigmata (rarely 4) up to 8 µm long. **Cheilocystidia** abundant, 20-46 × 5-9 µm, narrowly utriform, clavate or flexuose, thin-walled, hyaline. **Pleurocystidia** absent. **Lamellar trama** subregular; hyphae 2-8 µm wide, inflated up to 20 µm, hyaline to pale grey, thin-walled, inamyloid. **Subhymenium** cellular. **Pileal trama** interwoven, composed of branched, 2-23 µm wide, inflated, hyaline, thin- to slightly thick-walled (up to 1µm), inamyloid hyphae. **Pileal covering** mostly a repent cutis disrupted at the scales forming trichodermial patches but a trichodermial palisade at the disc with erect, compactly arranged clavate or cylindrical cystidioidal terminal elements; terminal elements 17-63 × 7-22 µm and with pale grey to grey plasmatic and encrusting pigments; certain hyphae originating from the pileal trama emerge through the compactly arranged elements and form an irregular covering over the palisade. **Stipe covering** a cutis of parallely arranged hyphae, 2-20 µm wide, hyaline to pale grey, thin- to thick-walled (up to 1 µm). All hypahe lack clamp-connections.

Habitat: On manure rich soil in open ground, solitary or scattered.

Known Distribution: The Lesser Antilles, Australia, the Carribean, Colombia, India, Mexico, USA, Venezuela.

Collections examined — Wayanad District, Muthanga: 2 June 2005, AK220; Calicut District, Pookad: 25 June 2005, AK296; 9 July 2005, AK296a.

The present collections agree with the description of *Leucoagaricus hortensis* (Pegler 1983; Akers & Sundberg 1997; Vrinda *et al.* 1999). Clamp-connections were absent in the present material, which agrees with the observation of type material by Murrill (1914, 1965) though their occurrence in the species has been later acknowledged (see Akers & Sundberg 1997).

This is a typically bisporic species as earlier recorded by Smith (1965), Pegler (1983) and Akers & Sundberg (1997). The present collections examined largely agree with this observation although rarely basidia with four sterigmata have also been observed. Earlier description of the species from Kerala by Vrinda *et al.* (1999) records all basidia in their materials as bearing four sterigmata. Pegler (1983) reports a similar observation on the species collected from Alabama and Trinidad where the materials possessed tetrasporic basidia.

Akers & Sundberg (1997) considers *Lepiota humei* Murrill, *L. mammillata* Murrill and *L. subfulvidisca* Murrill as synonymous with *L.*

hortensis, based on studies of the respective type specimens. This species is accepted here under *Chlorophyllum sensu* Vellinga (2002), amended on morphological and molecular grounds (Vellinga 2003c, 2004a).

Pegler (1983) as well as Reid (1993a) draws attention to the close similarity between the present species and *Leucoagaricus bisporus* Heinemann especially at the microscopic level. They differentiate these two species by the change of colour of the stipe on bruising: in the former species, it is more vinaceous. *Leucoagaricus bisporus* is strictly bisporic while four spored basidia are at times present in *Chlorophyllum hortense* (= *Leucoagaricus hortensis*).

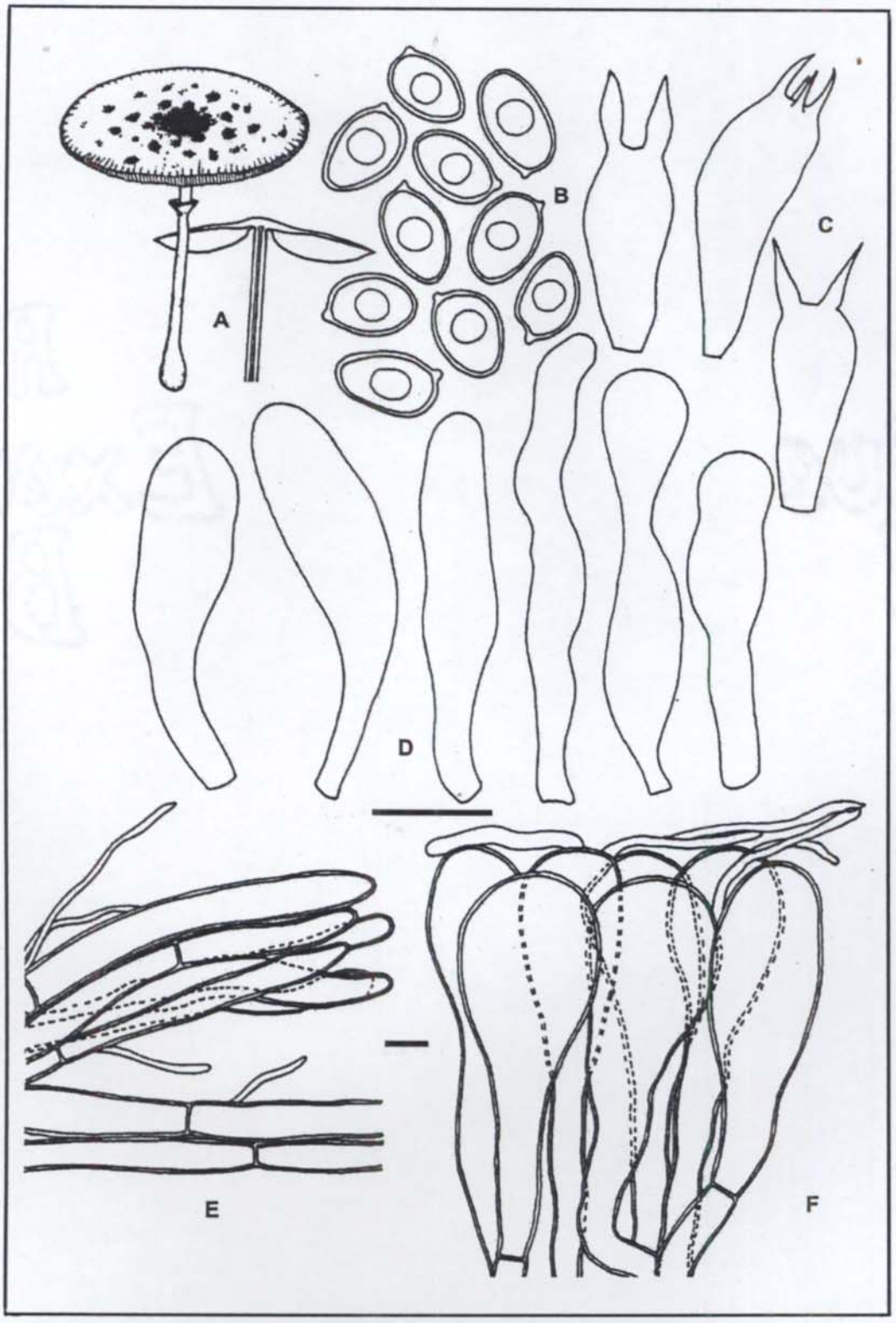


Figure 53. *Chlorophyllum hortense* **A.** Habit x 1 **B.** Spores **C.** Basidia **D.** Cheilocystidioa **E.** Stipe covering **F.** Pileus covering. Bars = 10 µm.

Plate 51. *Chlorophyllum brunneum* x 1

Plate 52. *Chlorophyllum hortense* x 1

Chlorophyllum abruptibulbum (Heim) Vellinga in Mycotaxon 83: 416 (2002)

Lepiota subprocera Beeli in Bulletin de la Société Royale de Botanique de Belgique 64: 212 (1932)

Leucocoprinus abruptibulbus Heim in Rivista de Mycologia 33: 213 (1968)

Macrolepiota abruptibulba (Heim) Heinemann in Bulletin de Jardin botanique national de Belgique 39: 218 (1969)

Fig. 54. A-F; Pl. 53. A & B.

Basidiomata medium-sized to somewhat large. **Pileus** 60-75 mm diam., subglobose to convex when young, becoming broadly convex to applanate, with an indistinct umbo; surface greyish brown (8D3, 8D4, 9D4), darker (6F8, 7E8) towards the disc, finely fibrillose; cuticle splitting radially and peeling off from the margin revealing the underlying white context; margin incurved, becoming straight, entire. **Lamellae** free, white, becoming yellowish white (3A2), turning light brown (6D7) on bruising or on ageing or on drying, moderately crowded to crowded, up to 15 mm wide, with lamellulae in 3-5 tiers; edge finely fimbriate under a lens, concolorous with the sides. **Stipe** 80-115 × 7-10 mm, central, terete, almost equal with a marginately bulbous base, solid; surface white to cream (4A3), turning orange grey (6B2) with age, turning rust brown (6E8) on bruising, fibrillose to rather villose; base arising from thick white mycelial cords. **Annulus** superior, membranous, initially fixed, movable with age. **Context** up to 8 mm thick, white, turning light brown (7D7) to dark brown (6F8) on exposure. **Odour** not distinctive. **Spore-print** white.

Spores 8-11.5 × 5-7.5 (9 ± 0.7 × 5.5 ± 0.66) µm, Q = 1.3-1.75, Qm = 1.5, broadly ellipsoid or amygdaliform, with a flattened base in some, with a rudimentary germ-pore in some, hyaline, with refractive guttules, thick-walled, smooth, dextrinoid, metachromatic in cresyl blue (metachromatism confined to a very thin layer), cyanophilous in cotton blue. **Basidia** 31-36 × 6-8 µm, clavate, bearing 4 sterigmata up to 5 µm long. **Lamella-edge** sterile with crowded cheilocystidia, disintegrating with age. **Cheilocystidia** 23-33 × 5-11 µm, clavate, at times strangulated, hyaline, thin-walled. **Pleurocystidia** absent. **Lamellar trama** subregular; hyphae 2-10 µm wide, hyaline, thin-walled, inamyloid. **Subhymenium** cellular. **Pileal trama** interwoven; hyphae 2-14 µm wide, hyaline, thin-walled, inamyloid. **Pileal covering** a differentiated cutis up to 100 µm wide that often split away from the underlying context; occasionally disrupted by ascending hyphae; hyphae 3-20 µm wide, cylindrical, thin-walled and with pale brown to brown plasmatic pigment. **Stipe covering** a cutis of repent hyphae, with occasional ascending or erect hyphal tips; hyphae thin-walled, hyaline or with a pale brown plasmatic pigment. Clamp-connections not observed.

Habitat: On soil, solitary.

Known Distribution: AFRICA

Collections examined — Calicut District, Kunduparamba: 20 May 2004, AK28; Puthiyangadi: 13 June 2004, AK54; 12 May 2006, AK462.

The medium-sized to large basidiomata of this species have pileal covering that splits up radially with expansion, revealing the white context below. The stipe has a distinct marginately bulbous base. The white context turns light brown to dark brown on exposure. It possess large spores usually without germ-pore or rarely a rudimentary one, showing metachromatism in cresyl blue and a cutis-type pileal covering that splits away as a layer from the pileal trama. Clamp-connections were not observed. All these characters make the present collections distinct and conspecific with the species described from Africa as *Leucocoprinus abruptibulbus* Heim (= *Macrolepiota abruptibulba* (Heim) Heinemann; *Lepiota subprocera* Beeli). However, the present collection shows the following variations from Heim's (1969) account: 1) germ pore almost absent in most spores, or very poorly developed, which is in contrast with the collections from Africa that possess spores with a very broad germ-pore (2.3-2.5 µm) 2) cystidia were recorded absent by Heim 3) in the Kerala collections, the elements of pileal covering were largely a differentiated layer of cutis, even at the disc, only with a few occasionally ascending hyphal elements. A study by Heinemann (1969) while designating a new combination for the species under *Macrolepiota*, also records spores having a broad germ-pore (2-2.2 µm). He observes abundant cheilocystidia in his materials, a character present in the Kerala collections. Beeli (1936) also records the presence of germ-pore in this species. The poorly developed germ pore and pileal covering that remains a cutis with occasionally ascending hyphal elements in the Kerala collections could just be anomalies at times encountered in nature.

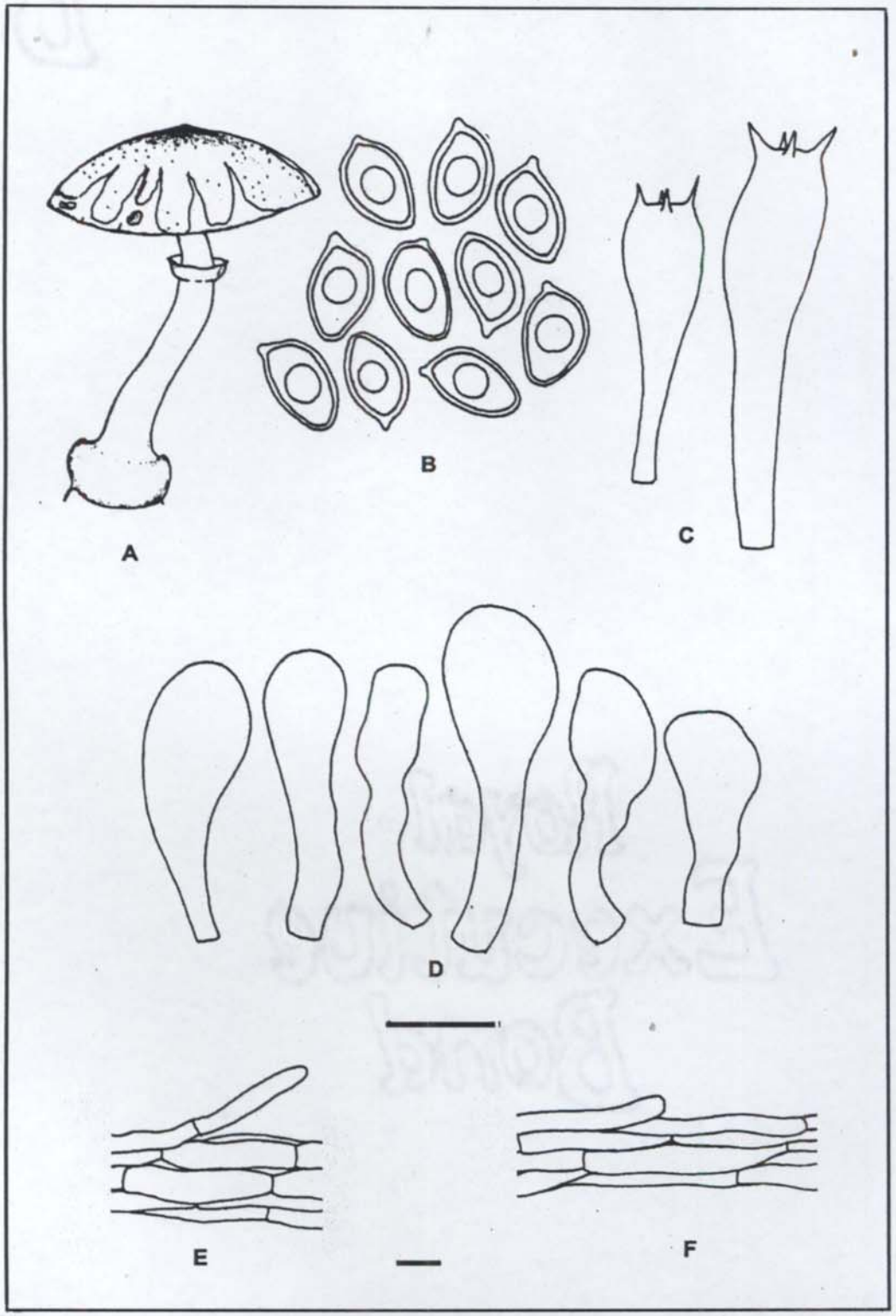


Figure 54. *Chlorophyllum abruptibulbum* **A.** Habit x 1 **B.** Spores **C.** Basidia **D.** Cheilocystidia **E.** Stipe covering **F.** Pileus covering. Bars = 10 µm.

Clarkeinda Kuntze

Agaricus Linneaus subgenus *Chitonia* Fries in Hymenomycetes Europaei: 277 (1874)

Chitonia (Fries) Karsten in Bidrag till Kännedom af Finlands Natur och Folk 32: 482 (1879), non Don (1823, *Melastomaceae*), Mociño & Sessé in DC (1824, *Zygophyllaceae*), Salisbury (1866, *Liliaceae*)

Clarkeinda Kuntze in Revisio generum plantarum 2: 848 (1891)

Chitoniella Massee in British Fungus-flora 1: 418 (1892), *nomen provisiorum*

Chitoniella Hennings in Engler & Prantl, Die natürlichen Pflanzenfamilien I Abt. 1** (13-15): 240 (1898)

Basidiomata large, fleshy; pileus with scattered squamules and a distinct persistant and rather thick pellicle at the disc; lamellae free, white turning yellowish white and later becoming greenish; stipe central, almost equal, bulbous at the base, fibrillose; annulus membranous, rather large, drooping, falling off with age; volva present, closely saccate; context white turning brown on bruising; spore-print greyish green; spores medium-sized, dextrinoid, metachromatic in cresyl blue, with a germ-pore, thick-walled; cheilocystidia present; pleurocystidia absent; lamellar trama subregular, of inflated hyphae; pileal covering a trichodermium of chains of barrel-shaped elements; stipe covering a cutis; clamp-connections absent.

Type species: *Clarkeinda trachodes* (Berkeley) Singer

This is a monotypic genus.

Clarkeinda trachodes (Berkeley) Singer in Lilloa 22: 413 ('1949') (1951)

Agaricus trachodes Berkeley in Hooker's London Journal of Botany 6: 487 bis (1847)

Chitoniella trachodes (Berkeley) Petch in Annals of the Royal Botanic Gardens, Peradeniya 4: 396 (1908)

- *Agaricus pedilius* Berkely & Broome in Journal of the Linnean Society, Botany 14: 32 (1873)

Chitonia pedilia (Berkeley & Broome) Saccardo in Sylloge Fungorum 5: 992 (1887)

Clarkeinda pedilia (Berkeley & Broome) Kuntze in Revisio Generum Plantarum 2: 848 (1891)

- *Agaricus podores* Berkeley & Broome in Journal of the Linnean Society, Botany 14: 32 (1873)

Chitonia podores (Berkeley & Broome) Saccardo in in Sylloge Fungorum 5: 992 (1887)

Clarkeinda podores (Berkeley & Broome) Kuntze in Revisio Generum Plantarum 2: 848 (1891)

Chitoniella podores (Berkeley & Broome) Hennings in Engler & Prantl (eds), Die natürlichen Pflanzenfamilien, 1, 1**: 240 (1898)

Fig. 55. A-F; Pl. 54.

Basidiomata large and fleshy. **Pileus** 90-200 mm diam., globose to subglobose when young, becoming convex to broadly convex and finally applanate, indistinctly umbonate when mature; surface pale yellow (4A2, 4A3), covered with concolorous erect and granular squamules towards the margin which later falls off on ageing, with a dark brown (8F7, 8F8), thick, lobate, plate-like pellicle covering the entire disc, finely striate at margin on ageing; margin incurved when young becoming straight, entire. **Lamellae** free, initially white, turning dull white and becoming greyish to dull green

(27D5, 27E5, 27E4, 27E3), crowded, up to 12 mm wide, with lamellulae in 3-5 lengths; edge finely fimbriate under a lens, concolorous with the sides. **Stipe** 100-160 × 12-20 mm (up to 25 mm at the base), central, terete, initially fistulose, becoming hollow, almost equal with a slight expansion towards a bulbous base; surface white, becoming dull white with maturity and turning yellowish brown (5E6, 5E8) or brown (5F8) on ageing and bruising, almost glabrous towards apex, granulose to rather velutinous towards the base. **Annulus** superior, thick, large and drooping, smooth above, floccose below, movable, falling off with age. **Volva** close-fitting, irregularly torn at the top, thin and membranous. **Context** up to 15 mm thick at the disc, thinner towards margin, white, turning brown (5E8) on bruising. **Odour** strong and unpleasant. **Spore-print** greyish green (1C4).

Spores 5-9 × 4-5 (6.5 ± 0.78 × 4.4 ± 0.48) µm, Q = 1.1-1.8, Qm = 1.47, mostly amygdaliform, occasionally ovate to ellipsoid, truncated by a germ-pore up to 1 µm broad, with a short hilar appendage, thick-walled, smooth, hyaline to mostly pale green, with guttulate contents, dextrinoid, mostly non-metachromatic, but a few weakly metachromatic in cresyl blue mounts, cyanophilic in cotton blue. **Basidia** 15-20 × 6-11 µm, cylindrico-clavate, thin-walled, hyaline, with oil guttules and 4 sterigmata up to 5 µm long. **Lamella-edge** sterile with abundant cheilocystidia. **Cheilocystidia** 19-65 × 12-45 µm, inflated-clavate, at times pyriform, hyaline, thin-walled. **Pleurocystidia** not observed. **Lamellar trama** subregular, of 3-40 µm wide, hyaline to pale grey, inflated, thin-walled, inamyloid hyphae. **Subhymenium**

narrow, compactly arranged with pseudoparanchymatous cells. **Pileal trama** composed of 3-29 µm wide, inflated, thin-walled, hyaline, inamyloid hyphae. **Pileal covering** a cutis; hyphae closely septate, compactly arranged, composed of short, cylindrical, inflated or almost isodiammetric elements, 20-27 × 12-20 µm, thin-walled, with hyaline to pale brown plasmatic pigment: the pellicle at the disc and the squamules formed of an agglutinated trichodermium of branched chains of barrel-shaped elements, 15-45 × 5-20 µm, thin-walled, with pale brown to brown vacuolar pigments. **Stipe covering** a cutis composed of inflated, 4-20 µm wide, thin-walled hyphae, closely septate and forming ascending chains of ellipsoid to cylindrical elements towards the hyphal tips. Clamp-connections not observed in any part.

Habitat: On soil and humus in shady places along roadsides, solitary.

Known Distribution: South East ASIA: India, Java, Malay Peninsula, Sri Lanka.

Collections examined — Malappuram District, Calicut University Campus: 2 July 2004, AK62; 20 September 2004, AK104; 20 October 2004, AK141; 1 November 2004, AK161; 10 June 2005, AK253; 12 August 2005, AK379; 18 August 2005, AK383; 11 September 2006, AK438; 9 October 2006, AK454; Calicut District, Thusharagiri: 22 July 2004, AK77; Peruvannamuzhi: 16 September 2004, AK101.

Clarkeinda trachodes has already been reported from Kerala by Leelavathy *et al.* (1981) providing a detailed description. Characters of the present collections very well match that of the earlier description from Kerala. The only mentionable variation is in their spore-print colour (noted as olive brown (4F8) by Leelavathy *et al.*) and slightly larger spore dimensions. The present collections also agree with the description given by Pegler (1985, 1986) based on material from Sri Lanka and the Malaysia. The spore-print colour in Pegler's descriptions is recorded as 'Sulphine Yellow (M.5Y/6.5/6.3) to Orange Citrine (M.2.5Y/4.9/6.0)' following the Ridgway color standard (Pegler 1985). Table 4 gives a comparison of the spore dimensions given by mycologists who have critically studied the taxon.

Table 4. Comparison of spore dimensions (in µm) from literature.

Pegler (1985, 1986)	Leelavathy *et al.* (1981)	Boedijn (1934) as *Chitoniella trachodes*	Petch (1908) as *Chitoniella podores*
5.5-8 × 4-5	6-7.5 × 3.5-4	5-8 × 3-4	6-8 × 3.5-4

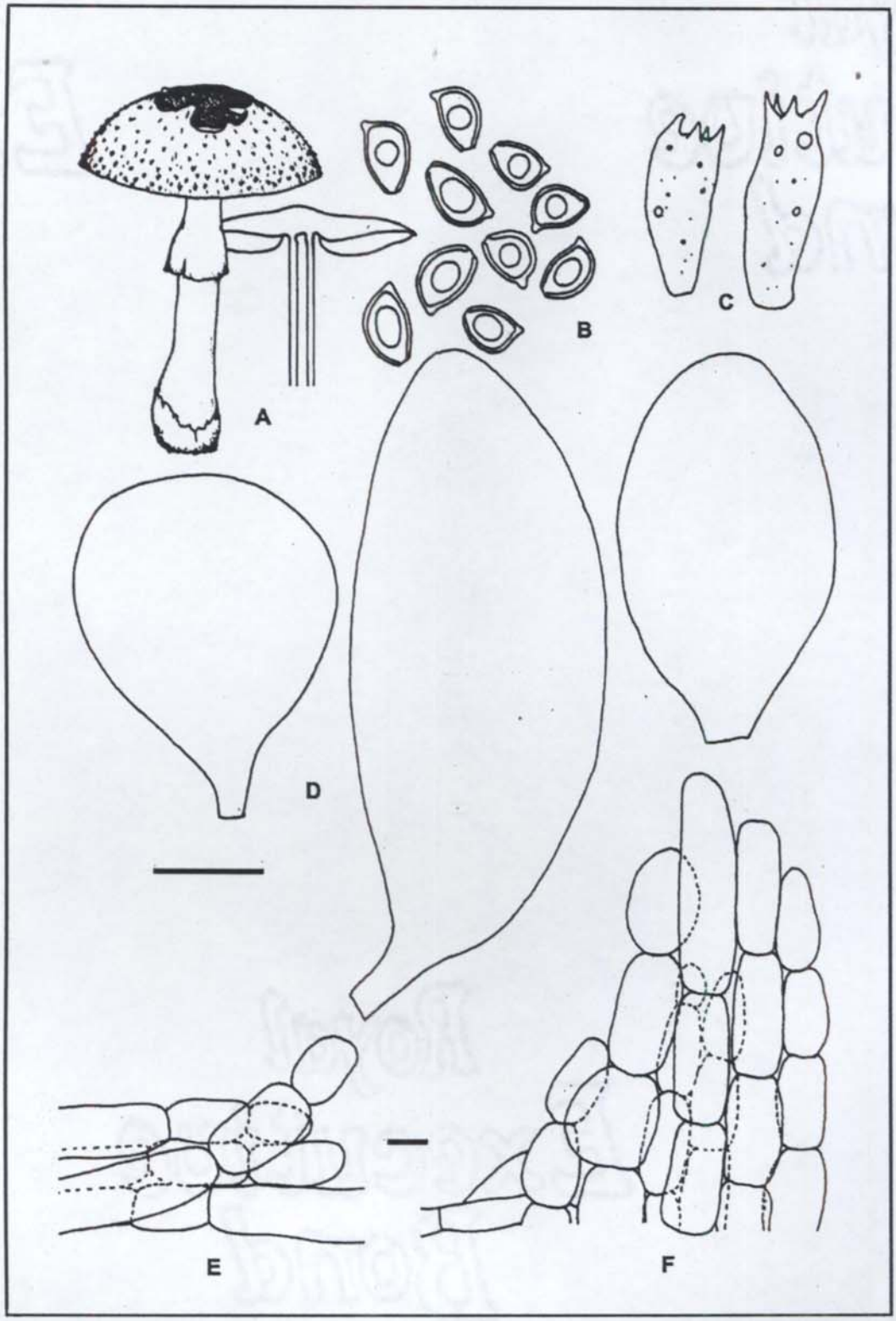


Figure 55. *Clarkeinda trachodes* **A.** Habit x 1 **B.** Spores **C.** Basidia **D.** Cheilocystidia **E.** Stipe covering **F.** Pileus covering. Bars = 10 µm.

Plate 53. *Chlorophyllum abruptibulbum,* **A. & B.** x 1

Plate 54. *Clarkeinda trachodes* x 1

A FLORISTIC STUDY OF THE LEPIOTACEOUS FUNGI OF KERALA AND SOME TAXONOMIC OBSERVATIONS ON THE GROUP

Thesis submitted to the University of Calicut
in partial fulfilment of the requirements for the Degree of
DOCTOR OF PHILOSOPHY
in Botany

By

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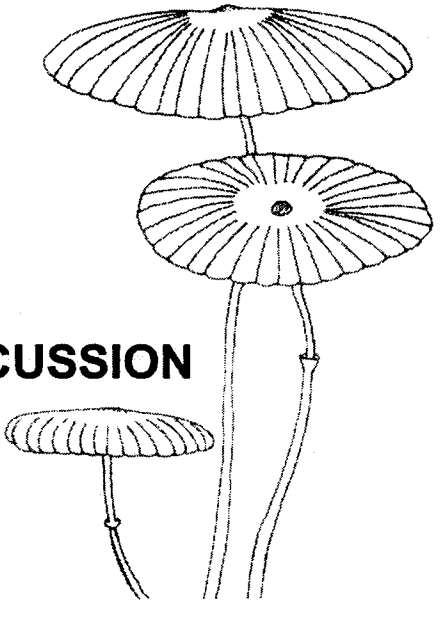
2007

Chapter 6



OBSERVATIONS AND DISCUSSION

Chapter- 6
OBSERVATIONS AND DISCUSSION

6.1 FLORISTIC OBSERVATIONS
6.1.1 General Observations

During this study that spanned over a period of three-and-a-half years, benefiting from seven collecting seasons, a total of 284 collections of lepiotaceous fungi were made by the author from different parts of Kerala. These collections represent fifty five taxa that are assigned to the following seven lepiotaceous genera: *Lepiota*, *Cystolepiota*, *Leucocoprinus*, *Leucoagaricus*, *Chlorophyllum*, *Macrolepiota* and *Clarkeinda*. Out of these, 21 taxa were found to be new to science. This includes eight species and one variety of *Lepiota*, one species of *Cystolepiota*, five species of *Leucocoprinus* (including *Leucocoprinus lacrymans* that has been validly published as new during the course of the study) and six species of *Leucoagaricus*. This study presents the first report of the genus *Macrolepiota* in Kerala.

6.1.1.1 Genus *Lepiota*

In this study, the genus *Lepiota* is represented by twenty two taxa. These belong to the following five sections of *Lepiota* recognized by Singer (1986):

Section *Lepiota*

1. *Lepiota metulaespora* (Berkeley & Broome) Saccardo

Section *Stenosporae*

2. *Lepiota griseovirens* Maire

3. *Lepiota erythrosticta* (Berkeley & Broome) Saccardo

4. *Lepiota castanea* Quelét

Section *Echinatae*

5. *Lepiota pseudoasperula* (Knudsen) Knudsen

6. *Lepiota* species 3

7. *Lepiota* species 5

Section *Ovisporae*

8. *Lepiota subincarnata* Lange

9. *Lepiota brevipes* Murrill

10. *Lepiota brevipes* variety 1

11. *Lepiota elaiophylla* Vellinga & Huijser

12. *Lepiota ianthinosquamosa* Pegler

13. *Lepiota viriditincta* (Berkeley & Broome) Saccardo

14. *Lepiota xanthophylla* Orton

15. *Lepiota* species 1

16. *Lepiota species 2*

17. *Lepiota* species 4

18. *Lepiota* species 6

19. *Lepiota* species 8

Section *Anomalae*

20. *Lepiota plumbicolor* (Berkeley & Broome) Saccardo

21. *Lepiota murino-capitata* Dennis

22. *Lepiota* species 7

Representative species for the sections, *Cristatae*, *Amyloideae* and *Amylosporae* have not been encountered in Kerala.

Of these, 21 taxa are first records for Kerala State. *Lepiota viriditincta* (Berkeley & Broome) Saccardo has already been reported by Manimohan *et al.* (1988). *L. guatopoensis* Dennis and *L. pyrrhaes* (Berkeley & Broome) Saccardo are two species that have earlier been reported from Kerala (Vrinda *et al.* 1999; 2001) but were not encountered during this study. Twenty taxa encountered during this study are first records for India. *Lepiota viriditincta* and *L. metulaespora* are the only other species earlier reported from India. *Lepiota erythrosticta*, *L. metulaespora*, *L. viriditincta* and *L. plumbicolor* had been reported from adjacent Sri Lanka by Pegler (1972, 1986) and have a pantropical distribution. The species *L. subincarnata* collected during this study has a cosmopolitan distribution, including a report from East Africa (Pegler 1977). *Lepiota castanea*, *L. griseovirens* and *L. xanthophylla* are also wide spread species. *Lepiota pseudoasperula* has so far been known only from the European and American continents. The collections of *L. elaiophylla* and *L. ianthinosquamosa* from Kerala prove to be their first reports outside their respective type localities. The following five species of *Lepiota* are new records to Asia:

1) *Lepiota subincarnata* Lange
2) *Lepiota brevipes* Murrill
3) *Lepiota elaiophylla* Vellinga & Huijser
4) *Lepiota ianthinosquamosa* Pegler
5) *Lepiota murino-capitata* Dennis

Two species of *Lepiota* encountered in Kerala, *L. viriditincta* and *L. species* 8, exhibit bluish to green colour change on bruising, indicating possible psilocybin content in their basidiomata.

6.1.1.2 Genus *Cystolepiota*

The species recognized as belonging to the genus are:

1. *Cystolepiota cystidiosa* (Smith) Bon
2. *Cystolepiota pulverulenta* (Huijsman) Vellinga
3. *Cystolepiota* species 1

Cystolepiota cystidiosa and *C. pulverulenta* collected during this study are new reports to India. *Cystolepiota hemisclera* is the only other *Cystolepiota* species earlier reported (Vrinda *et al.* 1997) from India. None of the above three species collected during this study have been reported by Pegler (1977, 1986) from East Africa or Sri Lanka, regions having general floristic similarities. The remarkable species *Cystolepiota cystidiosa* had been known only from Europe and USA and forms the first record of the species from Asia. It is the only lepiotaceous species known from Kerala with pleurocystidia.

6.1.1.3 Genus *Leucocoprinus*

Fifteen species belonging to the genus *Leucocoprinus* have been collected and studied from Kerala. An infrageneric classification has not been provided by Singer for this genus and hence the Kerala species is not classified into sections. The Kerala species of *Leucocoprinus* collected during this study are:

1. *Leucocoprinus birnbaumii* (Corda) Singer

2. *Leucocoprinus brebissoni* (Godey) Locquin
3. *Leucocoprinus cretaceus* (Bulliard: Fries) Locquin
4. *Leucocoprinus fragilissimus* (Berkeley & Curtis) Patouillard
5. *Leucocoprinus holospilotus* (Berkeley & Broome) Reid
6. *Leucocoprinus ianthinus* (Cooke) Locquin
7. *Leucocoprinus jubilaei* (Josserand) Wasser
8. *Leucocoprinus lacrymans* T. K. A. Kumar & Manimohan
9. *Leucocoprinus straminellus* (Baglietto) Narduci & Caroti
10. *Leucocoprinus submontagnei* Heinemann
11. *Leucocoprinus venezuelanus* Dennis
12. *Leucocoprinus* species 1
13. *Leucocoprinus* species 2
14. *Leucocoprinus* species 3
15. *Leucocoprinus* species 4

Of these, the following species have already been reported from Kerala by Vrinda *et al.* (1997; 2003): *Leucocoprinus birnbaumii*, *L. brebissoni*, *L. fragilissimus* and *L. venezuelanus*. All the other species are first records to Kerala and India. Pegler (1972, 1986) reported the species *L. holospilotus* from Sri Lanka under the genus *Lepiota*, but the presence of distinct leucocoprinean characters in the Kerala collections warrants its placement under *Leucocoprinus*. The following species of *Leucocoprinus* are first records to Asia:

1) *Leucocoprinus ianthinus* (Cooke) Locquin
2) *Leucocoprinus jubilaei* (Josserand) Wasser

3) *Leucocoprinus submontagnei* Heinemann

The *Leucocoprinus badhamii* complex that turn greenish on exposure to ammonia fumes were represented by two species (*L. holospilotus* and *L. lacrymans*) in this study.

During this study, it has been observed that pseudoparaphyses are a good character to delineate the genus *Leucocoprinus* from *Leucoagaricus* (see Singer 1986), although recent molecular studies (Vellinga 2004a) questions the validity of this character. Observations made during the course of this study on a number of both fresh and dried materials of species belonging to *Leucocoprinus*, also indicated that the presence of pseudoparaphyses is a strong distinguishing character of the genus as long as one follows the conventional morphology-based taxonomy. However, distinguishing pseudoparaphyses in the hymenium solely based on their shape seemed difficult in many cases. Remarkably, observations were made during this study to distinguish pseudoparaphyses on the basis of staining properties. Notable difference in the degree of staining between the pseudoparaphyses and other fertile cells in the hymenium was frequently evident with a mixture of Congo red and phloxine. Staining a cross section of lamella with a mixture of 1% aqueous solutions of phloxine and Congo red for 10 minutes and then washing with 3% aqueous KOH to remove excess stain, gave good results. Basidia were stained bright pinkish orange to red indicating a high affinity for both Congo red and phloxine while the pseudoparaphyses were stained much lighter. The cell walls of pseudoparaphyses were stained with the wall-specific Congo red, but the

inability to be stained with phloxine indicated an absence or shortage of cytoplasm. Plate 59. C. shows a section of the hymenium of a representative species (*Leucocoprinus birnbaumii,* Coll. No. AK82) with differentially stained basidia and pseudoparaphyses. Instant distinction of *Leucoagaricus* and *Leucocoprinus* species is possible by checking for pseudoparaphyses based on this differential staining.

6.1.1.4 Genus *Leucoagaricus*

Nine species have been studied and assigned to the genus *Leucoagaricus* of which three are new reports to Kerala as well as India and the remaining are new to science. The following are the Kerala species of *Leucoagaricus*:

1. *Leucoagaricus glabridiscus* (Sundberg) Wuilbaut
2. *Leucoagaricus rubrotinctus* (Peck) Singer
3. '*Lepiota viridiflava*' Petch (considered as a *Leucoagaricus* species in this treatise)
4. *Leucoagaricus* species 1
5. *Leucoagaricus* species 2
6. *Leucoagaricus* species 3
7. *Leucoagaricus* species 4
8. *Leucoagaricus* species 5
9. *Leucoagaricus* species 6

'*Lepiota viridiflava*', a species that turn bluish green on bruising has strong affinities that support its placement inside the genus *Leucoagaricus* and hence warrants a new combination. This species had been reported

only from Sri Lanka. The present collection from Kerala is the first record of this species outside its type locality and is a rediscovery exactly 90 years after its original publication. While *Leucoagaricus rubrotinctus* is known for its ubiquitous distribution, the very closely related *L. glabridiscus* is being recorded for the first time outside the USA and forms its first record from Asia.

6.1.1.5 Genus *Macrolepiota*

The only species of *Macrolepiota sensu* Vellinga encountered in Kerala is:

1. *Macrolepiota dolichaula* (Berkeley & Broome) Rayner

The species has already been reported from India by Manjula (1983), but this forms the first report of the genus from Kerala. The species is known to occur in East Africa (Pegler 1977) and Sri Lanka (Pegler 1986).

6.1.1.6 Genus *Chlorophyllum*

The genus *Chlorophyllum sensu* Vellinga is represented in this study by four species. They are:

1. *Chlorophyllum abruptibulbum* (Heim) Vellinga
2. *Chlorophyllum brunneum* (Farlow & Burt) Vellinga
3. *Chlorophyllum hortense* (Murrill) Vellinga
4. *Chlorophyllum molybdites* (Meyer: Fries) Massee

Chlorophyllum abruptibulbum is a new record to Asia. The species *C. hortense* has already been reported from Kerala under the genus *Leucoagaricus* (Vrinda *et al.* 1999). *C. brunneum* is a new record to Kerala.

This species seems to be identical with the species reported by Gosh & Pathak (1965) from Lucknow, India as *Macrolepiota rhacodes*.

6.1.1.7 Genus *Clarkeinda*

The only known species of the genus *Clarkeinda* is:

1. *Clarkeinda trachodes* (Berkeley) Singer

The species had already been reported from Kerala by Leelavathy *et al.* (1981)

6.1.1.8 Species diversity

A study of the lepiotaceous species of Kerala indicates affinities with both tropical as well as temperate lepiotaceous mycota. The lepiotaceous mycota of Kerala showed good similarity with that of Sri Lanka.

Results of the present study more or less agree with Vellinga's (2004b) observation that the *Leucoagaricus* and *Leucocoprinus* species are more common in the tropics. However, out of the total collections made during this study, the highest number of collections belonged to the genus *Lepiota*, followed by *Leucocoprinus*. *Leucoagaricus* collections were relatively low and were only about half that of the collections of *Lepiota* or *Leucocoprinus*. All the other taxa were relatively less frequent in fruiting and were fairly less diverse with species strength of one to four. Graph 1 represents the relative abundance of the seven lepiotaceous genera encountered during the study. Calicut University campus proved to harbour a rich lepiotaceous mycota with 32 species. The existence of such localized hotspots is known for lepiotaceous fungi as already observed by Vellinga (2004b).

6.1.1.9 Fruiting pattern

Fruiting inconsistency of species was another major feature noted during this study. Most of the taxa except a few showed irregularities in fruiting and fruiting were not observed in the same location every season. This was confirmed by constantly monitoring the Calicut University campus and the Puthiyangadi area of Malappuram and Calicut districts respectively for the presence of basidiomata. Most of the species fruited solitarily. This observation corresponds with that of Vellinga (2004b) on tropical lepiotaceous species.

Fruiting commenced from April and continued till November. With onset of the South west monsoon, basidiomata of *Chlorophyllum*, *Leucoagaricus* and *Leucocoprinus* species are the first to appear. *Chlorophyllum* species cease fruiting with the increase in south-west monsoonal rain fall and reappear with the start of the north-east monsoon, while species of the genus *Leucoagaricus* and *Leucocoprinus* were observed to fruit throughout the two rainy seasons. Species of *Leucocoprinus* showed a comparatively more consistent fruiting pattern and abundance. Species of the genus *Lepiota* was observed to fruit throughout the two rainy seasons with a fruiting peak in the months of October and November. The relative fruiting frequency of *Lepiota* species increased in June, July, October and November, and may perhaps be due to the increasing precipitation, usually experienced during these months in the State. The genus *Clarkeinda* was observed to fruit from June and *Cystolepiota* from July to Novemeber, while *Macrolepiota* prefers the North

east monsoon period. Fruiting patterns observed in the lepiotaceous genera of Kerala during study duration is presented in Graph 2.

This is only a preliminary floristic study of the lepiotaceous fungi of Kerala State, carried out within a limited time frame of three and a half years. The range and diversity of species evident from this pioneering study gives an approximate indication of the floristic richness. However, much more species are likely to exist in the region some of which might have either failed to fruit for want of favourable conditions or evaded observation and collection during the course of the study. Also, several species may be thriving well in those places not visited by this author. Therefore, much more intensive and extended studies are essential to further bring out the exact state of diversity of this group in this part of the world.

6.2 Integrated light and electron microscopic studies on cheilocystidia and pileus covering of three lepiotaceous taxa

Integrated light and electron microscopic studies on the cystidia and pileal covering of three lepiotaceous taxa provided details on their approximate cytochemistry and subcellular composition.

6.2.1 Morphology and ultrastructure of cheilocystidia

6.2.1.1 *Chlorophyllum molybdites*

Intact cheilocystidia were clavate in shape, occasionally septate, thin-walled and appeared hyaline when mounted in water. In Periodic Acid-Schiff (PAS) reagent and toluidine blue (TB), green globular contents were observed. The greenish contents present in the cheilocystidia could well be the pigments present in the taxa that provide greenish colour to its spores

and lamellae. The cell wall was stained red in PAS but the cytoplasm apart from the green bodies remained unstained indicating an absence of or highly reduced cellular contents (Plate 55. A & B). A blue to bluish green cell wall and an unstained or pale blue cytoplasm in TB, gave identical results indicating loss of cytoplasmic contents (Plate 55. C). At the same time, ultrastructural observation (Plate 56. A & B) showed cytoplasm in young cheilocystidia, significantly lacking distinguishable organelles thereby pointing to a reduced level of metabolic activity in the cell. Large vacuoles were observed in the cells with electron-dense bodies inside, mainly settled towards the vacuolar membrane. These electron-opaque bodies correspond to the greenish globular contents in PAS- and TB-stained cells clearly visible under the light microscope. In mature cheilocystidium, the cytoplasmic contents were found degenerated, along with an almost entire vacuolation of the cell (Plate 56. C) demonstrating similarities with the cytological developments in cystidia of *Pluteus cervinus* (Schaeffer) Kummer (Strack & Sundberg 1981) where increased vacuolation restricted the cytoplasm to the periphery of the cystidium. The electron dense inclusions remained inside the big vacuole. Thielke (1982) had observed similar dark inclusions inside big vesicles in cystidia of *Volvariella bombycina* (Schaeffer) Singer but did not define the chemistry of the possible excretion product (see Clémençon 2004). TB is known to stain polyphenols green or blue green (Feder & O'Brien 1968), but the retention of the green colour of these bodies found in *C. molybdites*, even in PAS that stain some phenolics red, demands further chemical analysis to determine their exact chemical nature. The nature of

the cystidia in *C. molybdites* refers them to the leptocystidia type (Clémençon 2004) that is mainly excretory in function. The initially observed cytoplasmic contents may have a role as nutrient reservoirs and subsequently with their gradual depletion or degeneration on maturity, the cells may be acting as either secretory or excretory structures.

6.2.1.2 *Lepiota clypeolaria*

The cheilocystidia are clavate, hyaline and thin-walled. The cell wall was stained red but cytoplasm was pale red to almost unstained in PAS reagent (Plate 55. D). In TB, the cell wall showed a metachromatic reaction with purple colour, and the cytoplasm was stained deep blue except for the unstained vacuoles (Plate 55. E). A purple to red colour is a possible indication of the presence of some organic acids and a dark blue cytoplasm reveals a rich cellular contents. The exact chemical nature of the contents remains unclear but electron micrographs (Plate 56. D-F) reveals rich cytoplasmic inclusions including high ribosome content. Vacuoles are found distributed throughout the cytoplasm. The cheilocystidia in *L. clypeolaria* are metabolically active cells and the absence of any unusual dense inclusions characteristically found only in excretory cells point to storage as their possible role.

6.2.1.3 *Leucoagaricus leucothites*

The cheilocystidia at the lamella-edge of the species were found to slightly agglutinate (Plate 55. F & G) as also evident from the electron micrograph (Plate 56. I), showing the presence of a diffused zone of fibrillar matrix covering the cell wall. The thin cell-wall of the cheilocystidia stained

dark red in PAS reagent and the cytoplasm pale red with scattered darker spots. Starch and complex polysaccharides are known to be stained red in PAS (Feder & O'Brien 1968) (cellulose not stained). This may explain the dark red colouration in the cell wall region, possibly due to the presence of polysaccharides in the middle lamellae and additionally with the presence of the mucilaginous content that gives the cheilocystidia an agglutinated appearance. The presence of red spots in the cytoplasm also may be due to some polysaccharide contents. The cell wall and cytoplasm is stained blue in toluidine blue. The cytoplasm displays large round deeply stained red bodies indicating the possible presence of some polyphosphates, polysulphates and polycarboxylic acids including alginic and pectic acids (see Feder & O'Brien 1968). Cystidial ultrastructure presents these bodies as large electron dense areas.

A table summarizing the colour reaction results of cheilocystidial staining for light microscopy is given below:

Table 5. Colour reaction of cheilocystidia stained with Periodic Acid-Schiff reagent and Toluidine blue

Species	Part of Cell	PAS	TB
Chlorophyllum molybdites	Cell wall	Red	Blue to bluish green
	Cytoplasm	Unstained	Almost unstained, with green droplets
Lepiota clypeolaria	Cell wall	Red	Purple
	Cytoplasm	Pale red, with a few red granules	Blue, vacuoles unstained
Leucoagaricus leucothites	Cell wall	Dark red	Blue
	Cytoplasm	Pale red, with red spots	Blue, with numerous red darkly stained bodies

6.2.2 Morphology and ultrastructure of Pileus covering

6.2.2.1 *Chlorophyllum molybdites*

The pileal elements were erect and densely packed with an uppermost portion having an agglutinated appearance. In PAS reagent, the cell walls were stained bright red but the cells appeared empty with only a little staining in some (Plate 57. A). Electron micrographs (Plate 58. A &B) of the pileal covering display a thick darker outer layer with a dense matrix-like appearance. A few spores are found trapped in this outer layer (Plate 58. A). A close-up view of the deeply stained outer layer (Plate 58. B), reveals several membranous folds with abundant fibrillar matrix in between. These membranous folds may presumably be the collapsed cells located towards the outer layer. This layer, with relatively thick walls and without rich cytoplasm and appearing as a layer of protective cells of the pileal covering,

most probably represents cells derived from the universal veil. Staining with toluidine blue indicated the presence of some organic acids which appeared as red granules inside the cytoplasm (Plate 57. B & C). However, electron microscopic observations did not yield results confirming the solid presence of any such chemical concentrates.

6.2.2.2 *Lepiota clypeolaria*

The pileus covering is a trichodermium with erect fusoid elements with cell wall that stain dark red in PAS reagent and dark blue in TB (Plate 57. D & E). A few red granular spots indicating the presence of some polysaccharides were present in the cytoplasm stained with PAS reagent. Electron micrographs (Plate 58. C & D) showed a relatively thick cell wall with an outer diffuse zone of fibrillar matrix. The cytoplasm was found to be denegenerated.

6.2.2.3 *Leucoagaricus leucothites*

Pileus covering has a strongly agglutinated outer layer which deeply stains red in PAS reagent and reddish in TB (Plate 57 F-H) pointing to the probable presence of some complex polysaccharides, polyphosphates, polysulphates and polycarboxylic acids in the cell wall and glutinous matrix. The terminal hyphal cells in particular had rich cytoplasmic contents. Red to brown granules was distinctly visible on staining with toluidine blue indicating the presence of inclusions with possible acidic content (Plate 57. H). These contents in the cytoplasm appear as darkly stained round bodies when observed under the electron microscope (Plate 58. E & F). The cytoplasm is rich with unidentifiable granular contents, but cell organelles were not

observed. Dense fibrillar matrix is found outside the thin cell wall layer, possibly causing the agglutination of adjacent elements (Plate 58. F).

A summary of staining results of the pileal covering is represented in the table below:

Table 6. Colour reaction of elements of pileus covering stained with Periodic Acid-Sciff reagent and Toluidine blue

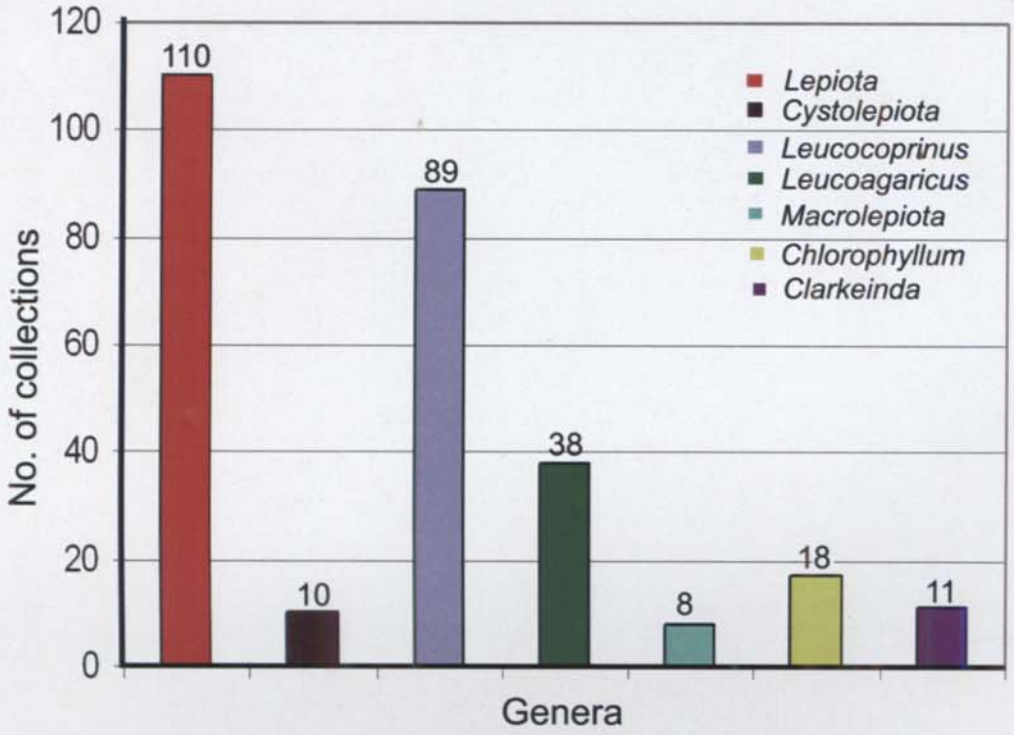
Species	Part of cell	PAS	TB
Chlorophyllum molybdites	Cell wall	Dark red	Light blue
	Cytoplasm	Unstained	Light blue, with red granules
Lepiota clypeolaria	Cell wall	Dark red	Dark blue
	Cytoplasm	Pale red, with a few red granules	Light blue
Leucoagaricus leucothites	Cell wall	Dark red	Reddish
	Cytoplasm	Pale red, with red spots	Blue, with numerous red to brown granules

The presence of cheilocystidia with highly degenerated cytoplasmic contents and unique dense inclusions in *Chlorophyllum molybdites* help in differentiating it from *Leucoagaricus leucothites* and *Lepiota clypeolaria*. The cheilocystidia of *L. leucothites* had a granular matrix covering the cell wall which was found absent in the other two taxa. Ribosomes were observed to be rich in the cytosol of *L. clypeolaria*, a feature not observed in cystidia of *C. molybdites.* and *L. leucothites*.

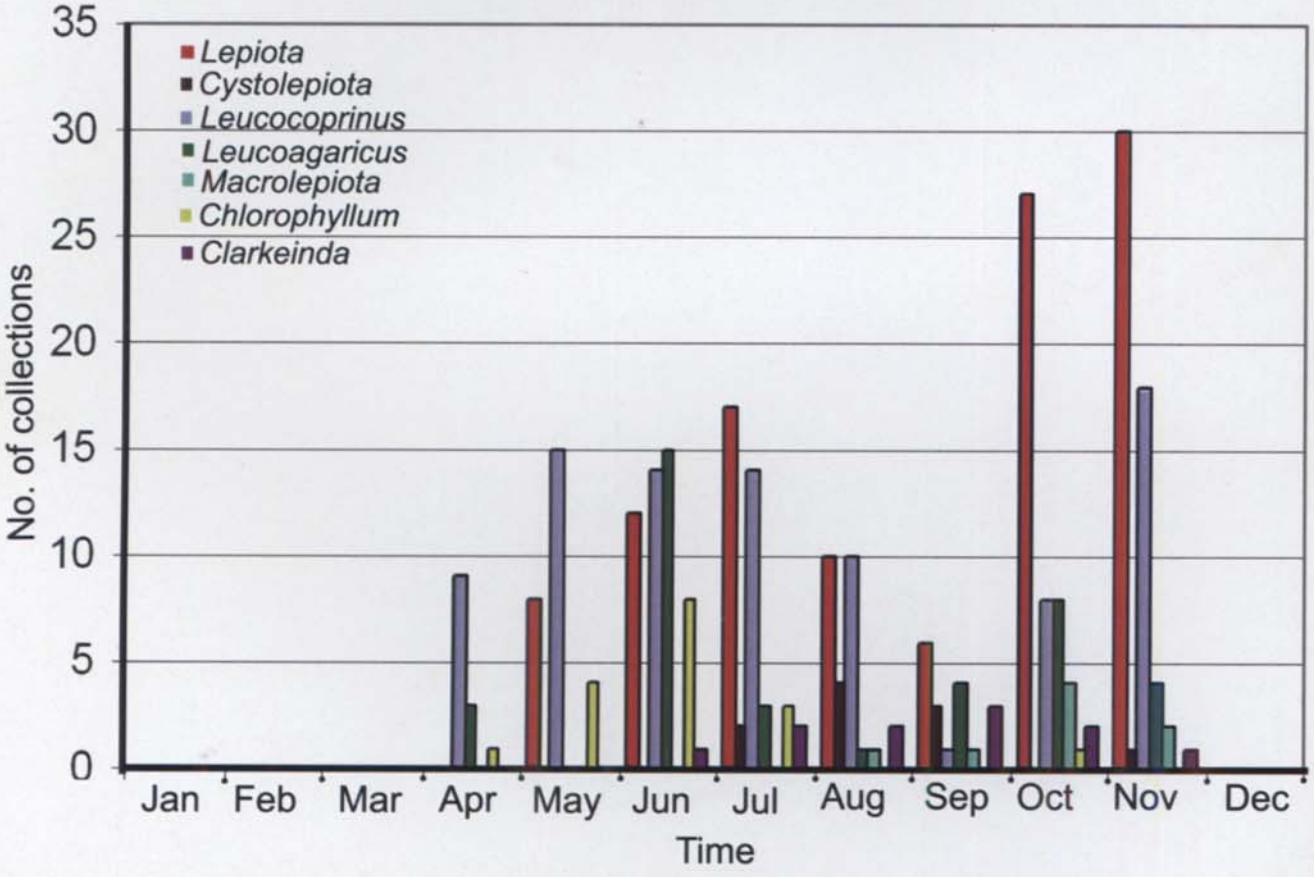
The elements of pileal cover in *Chlorophyllum molybdites* were tightly packed, mostly collapsed towards the outer portion, and covered by a matrix.

Cells towards the outer layer had a highly degenerated cytoplasm. In contrast, the pileal cells in *Lepiota clypeolaria* had loosely packed cells with rich cytoplasm. Most of the terminal cells of the pileal covering in *Leucoagaricus leucothites* were cytoplasm-rich, and distinct with dense globular cytoplasmic inclusions.

The possibility of ultrastructure-cytotaxonomy in lepiotaceous fungi is thus explored for the first time based on these three taxa. Significant distinctions in the arrangement and cellular composition were evident from the preliminary integrated light microscopic and ultrastructural observations. The results indicate a potential taxonomic value for such studies. It seems that with further investigations, reliable subcellular markers diagnostic of certain taxa can be identified to supplement the currently employed morphology and molecule-based information on lepiotaceous fungi.



Graph 1. Relative abundance of the seven lepiotaceous genera encountered in Kerala, during the study period .



Graph 2. Fruiting patterns of lepiotaceous genera in Kerala during the study period.

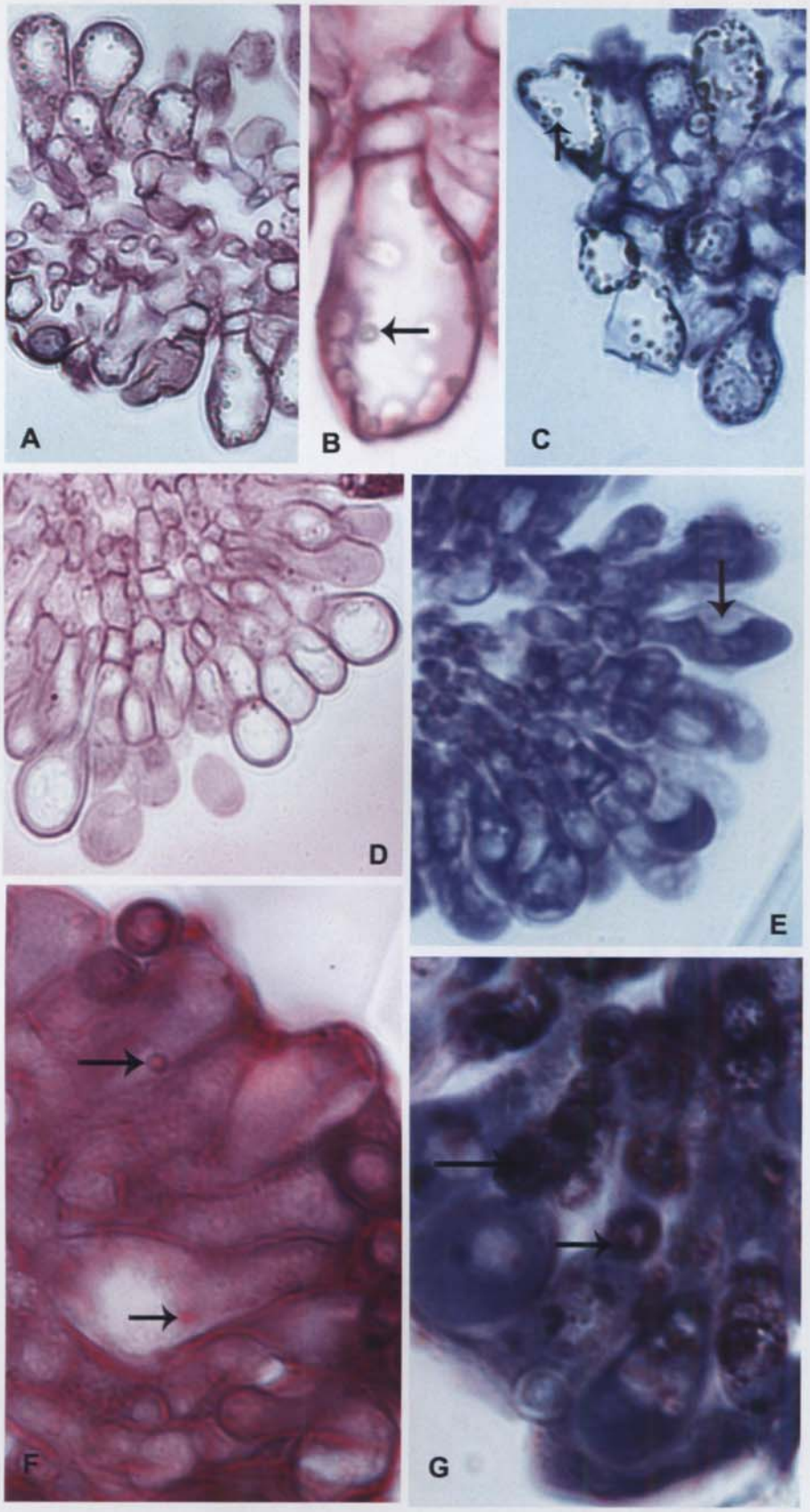


Plate 55. A & B. Cheilocystidia of Chlorophyllum molybdites in PAS. **A.** x 600. **B.** Cheilocystidia of *C. molybdites* with green globular contents (arrow) x 2000. **C.** Cheilocystidia of *C. molybdites* in TB. Green inclusions indicated by aroow x 800. **D.** Cheilocystidia of *Lepiota clypeolaria* in PAS x 800. **E.** Cheilocystidia of *L. clypeolaria* in TB x 800. Vacuole indicated by arrow. **F.** Cheilocystidia of *Leco-agaricus leucothites* in PAS x 2000. **G.** Cheilocystidia of *L. leucothites* in TB x 2000. Arrows indicating differently stained inclusions.

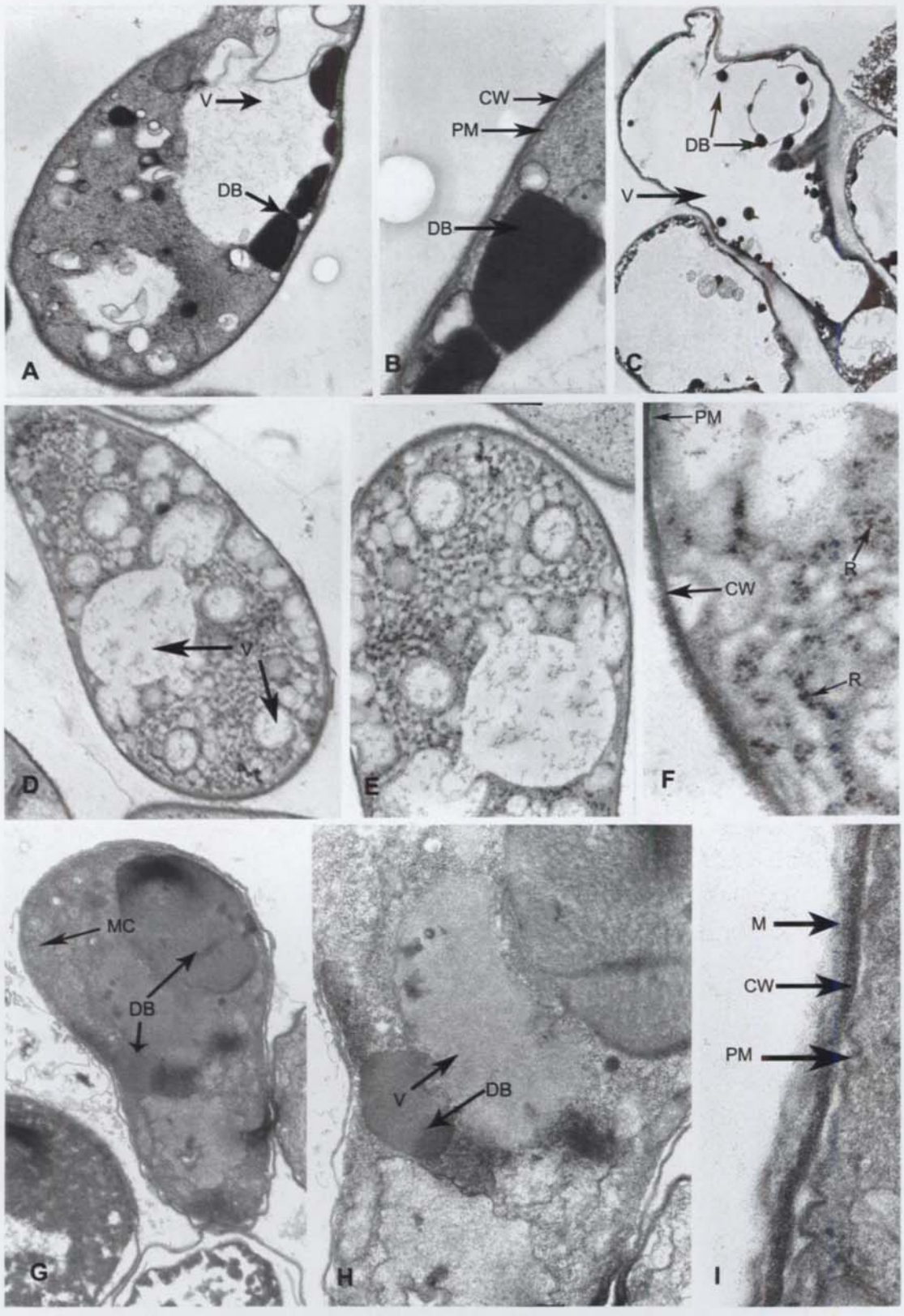


Plate 56. Cystidial ultrastructure of three lepiotaceous taxa. **A.** Cellular content rich young cheilocystidium in *C. molybdites*, showing large vacuoles (V) and large electron-dense bodies (DB) x 17000. **B.** A portion of cheilocystidium in *C. molybdites* showing cell-wall (CW), plasma membrane (PM) and electron-dense bodies x 45000. **C.** Mature cheilocystidium of *C. molybd* completely vacuolated, with electron bodies x 5000. **D** & **E.** Cytoplasm rich cheilocystidium of *Lepiota clypeolaria* with promin vacuoles x 3000 & 5000. **F.** Magnified view of the cheilocystidium in *L. clypeolaria,* showing cell wall, plasma membrane and numerous ribosomes (R) x 45000. **G - I.** Cytoplasm-rich cheilocystidia of *Leucoagaricus leucothites*. **G** & **H.** Cytoplasm with mitochondrion (MC), dense bodies x 3000 and vacuoles x 17000. **I.** Magnified portion showing the cell wall covered with gran matrix x 45000.

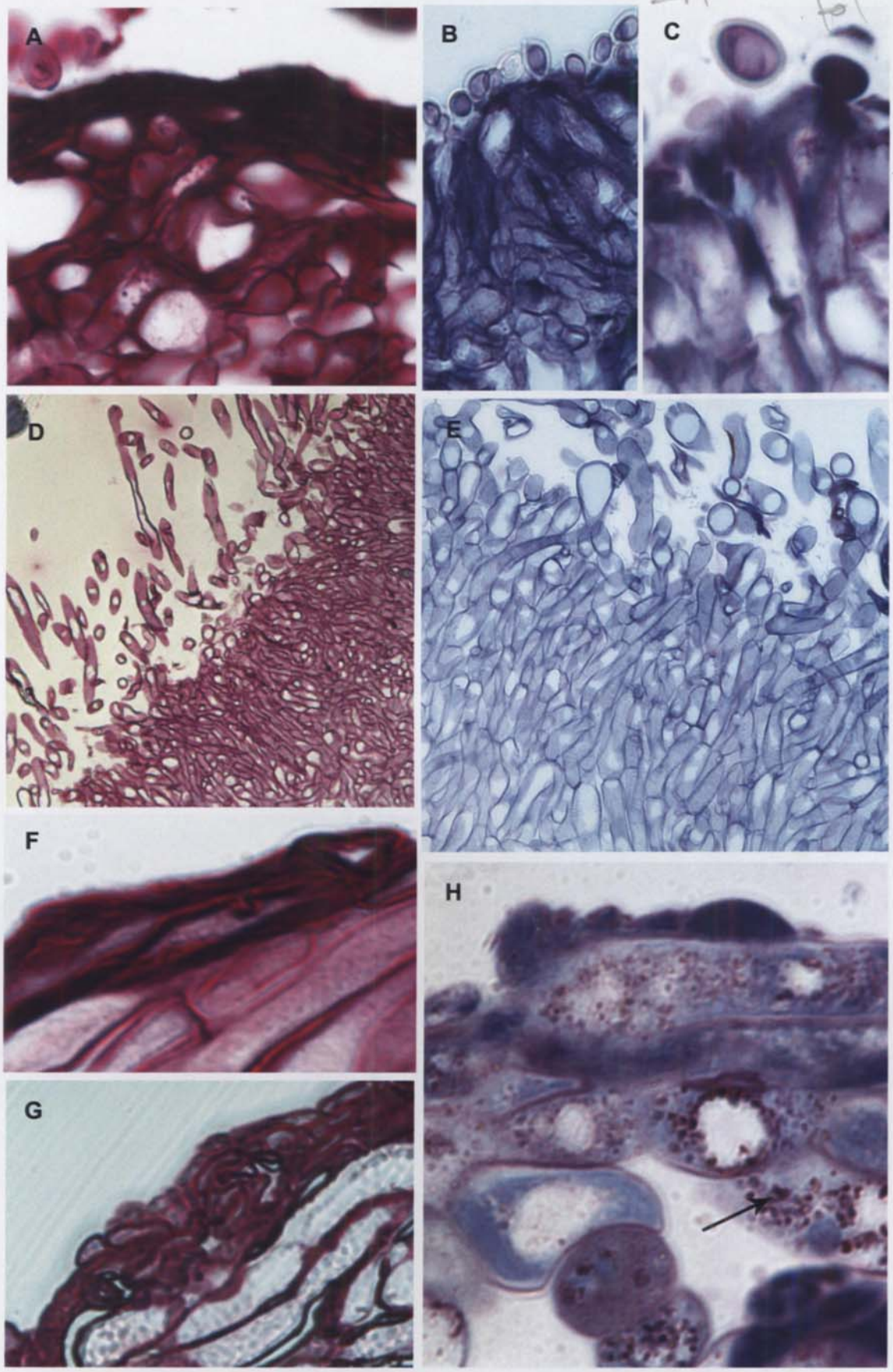


Plate 57. A. Pileus covering of *Chlorophyllum molybdites* in PAS x 4000. **B.** Pileus covering of *C. molybdites* in TB x 2000. **C.** Pileus covering of *C. molybdites* in TB x 4000. **D.** Pileus covering of *Lepiota clypeolaria* in PAS x 600. **E.** Pileus covering of *L. clypeolaria* in TB x 1500. **F.** & **G.** Pileus covering of *Leucoagaricus leucothites* in PAS. **F.** x 2500. **G.** x 2000. **H.** Pileus covering of *L. leucothites* in TB x 4000. arrows indicate granular contents.

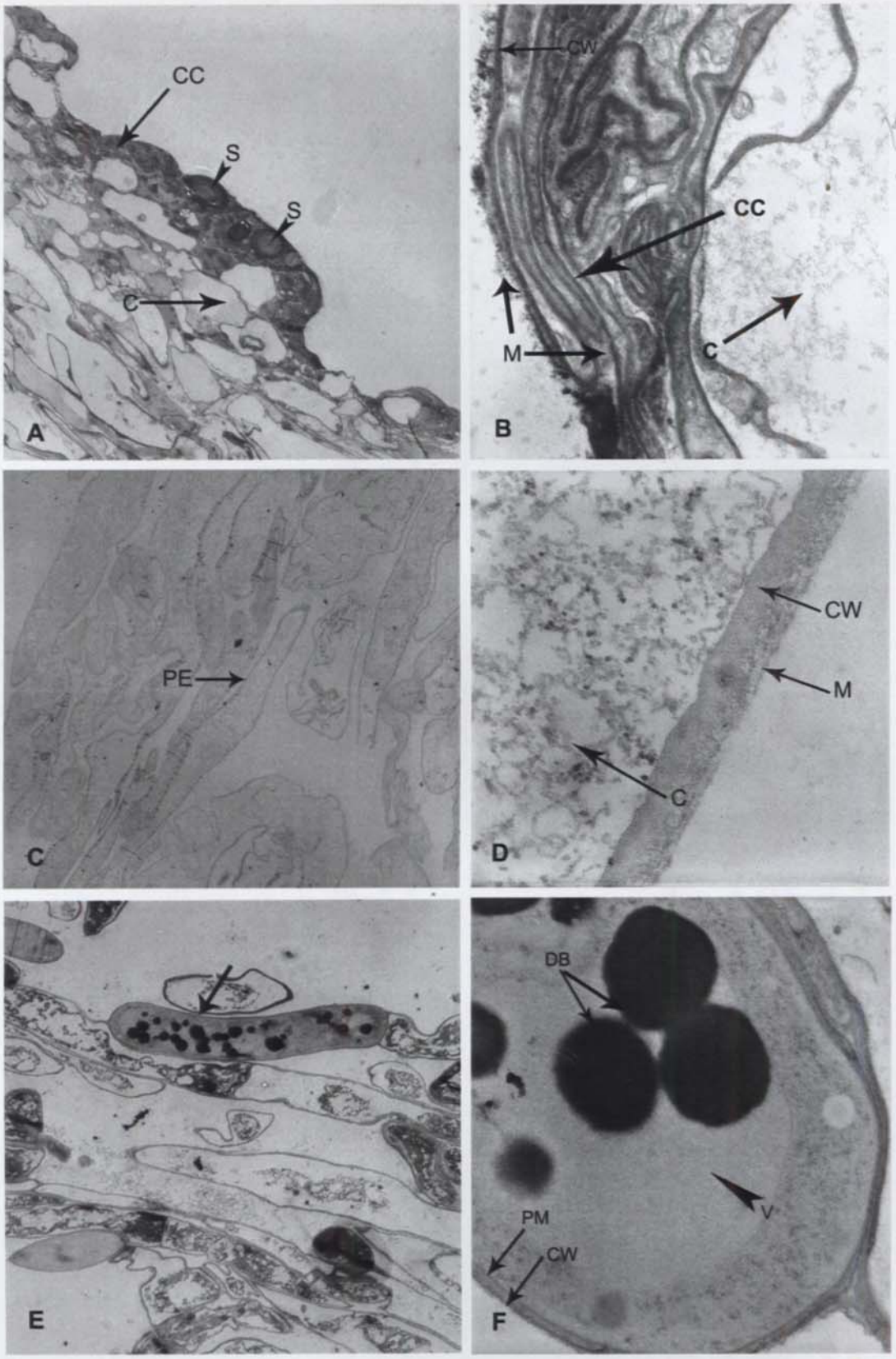


Plate 58. Ultrastructure of pileus covering in three lepiotaceous taxa. **A & B.** Pileus covering of *Chlorophyllum molybdites*. **A.** Agglutinated upper most layer of the pileus with spores entrapped in the matrix, densely packed cells below x 1000. **B.** Uppermost portion magnified x 22000, showing collapsed cells (CC), cell wall (CW), matrix (M) and degenerating cytoplasm (C). **C & D.** Pileus elements (PE) of *Lepiota clypeolaria*. **C.** x 1000. **D.** Magnified view of pileal elements showing cell wal covered by a matrix layer and cytoplasm x 45000. **E & F.** Pileus covering of *Leucoagaricus leucothites*. **E.** A terminal cell with rich cytoplasm (arrow) x 1400. **F.** Cell wall, plasma membrane (PM), vacuole (V) and electron dense bodies inside the terminal cell x 17000.

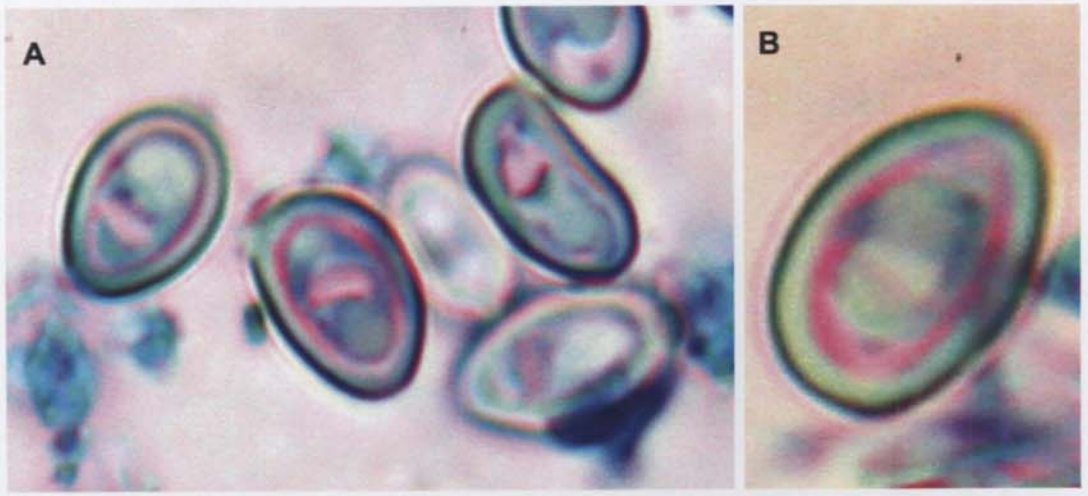


Plate 59. A. & **B.** Spores of '*Lepiota viridiflava*' metachromatic in cresyl blue x 2000. **C.** Hymenium encountered in *Leucocoprinus* species, with basidia (b) surrounded by pseudoparaphyses (p) . Basidia are strongly stained with Congo red, while the pseudoparaphyses are stained with phloxine alone x 800.

A FLORISTIC STUDY OF THE LEPIOTACEOUS FUNGI OF KERALA AND SOME TAXONOMIC OBSERVATIONS ON THE GROUP

Thesis submitted to the University of Calicut
in partial fulfilment of the requirements for the Degree of
DOCTOR OF PHILOSOPHY
in Botany

By

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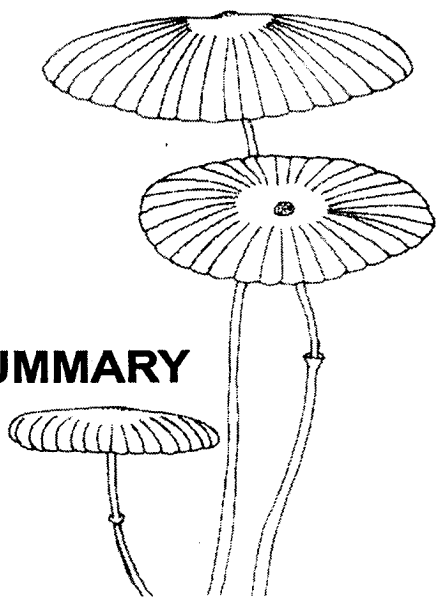
2007

Chapter 7



SUMMARY

Chapter 7
SUMMARY

This treatise presents the results of a preliminary floristic study of lepiotaceous fungi as they occur in Kerala State, India. A total of 55 taxa, including 22 belonging to the genus *Lepiota*, 15 to *Leucocoprinus*, nine to *Leucoagaricus*, four to *Chlorophyllum*, three to *Cystolepiota* and one each to *Macrolepiota* and *Clarkeinda*, are fully described and illustrated.

A review of literature introduces the lepiotaceous fungi and gives its taxonomic history including the most recent generic concepts evolved. An outline of the taxonomically useful characters of the group, genera involved, and the impact of molecular phylogenetic studies on the generic concepts is presented. Literature on the biology and ecology, economic importance and geographic distribution is also reviewed.

Conventional morphology-based techniques were used for the floristic study. Combined light microscopy and transmission electron microscopy were employed for additional taxonomic investigations.

Fifty four species and one variety belonging to seven genera were identified based on fresh collections made from different localities of Kerala during a three-and-a-half year study period. Keys are provided wherever applicable, to the genera, sections and species of the group encountered in Kerala. Species descriptions are supplemented with synonymy, author citations, collection data, and information on their known distribution.

Photographs are given for all species except *Lepiota* species 3, and these depict the agarics in their natural stature, colour and habitat. Line drawings are provided for all the microscopic characters observed.

The study resulted in the discovery of 21 taxa new to science. Of these 20 are new species and one a new variety. This includes eight new species and one new variety belonging to the genus *Lepiota*, six new species of the genus *Leucoagaricus*, five of the genus *Leucocoprinus* (including *Leucocoprinus lacrymans* that has been validly published as new during the course of the study) and one new species to the genus *Cystolepiota*.

Out of the remaining 35 lepiotaceous species encountered in Kerala, 11 species are new reports to Asia. This includes the following five species of *Lepiota*, three species of *Leucocoprinus*, two species of *Leucoagaricus* and one species each of *Chlorophyllum* and *Cystolepiota*.

1) *Lepiota subincarnata* Lange
2) *Lepiota brevipes* Murrill
3) *Lepiota elaiophylla* Vellinga & Huijser
4) *Lepiota ianthinosquamosa* Pegler
5) *Lepiota murino-capitata* Dennis
6) *Leucocoprinus ianthinus* (Cooke) Locquin
7) *Leucocoprinus jubilaei* (Josserand) Wasser
8) *Leucocoprinus submontagnei* Heinemann
9) *Leucoagaricus glabridiscus* (Sundberg) Wuilbaut

10)*Chlorophyllum abruptibulbum* (Heim) Vellinga

11)*Cystolepiota cystidiosa* (Smith) Bon

The following 23 species are new records to India (excluding *Leucocoprinus lacrymans* T. K. A. Kumar & Manimohan):

1) *Lepiota castanea* Quelét

2) *Lepiota erythrosticta* (Berkeley & Broome) Saccardo

3) *Lepiota griseovirens* Maire

4) *Lepiota pseudoasperula* (Knudsen) Knudsen

5) *Lepiota brevipes* Murrill

6) *Lepiota elaiophylla* Vellinga & Huijser

7) *Lepiota ianthinosquamosa* Pegler

8) *Lepiota subincarnata* Lange

9) *Lepiota xanthophylla* Orton

10) *Lepiota plumbicolor* (Berkeley & Broome) Saccardo

11) *Lepiota murino-capitata* Dennis

12) *Cystolepiota cystidiosa* (Smith) Bon

13) *Cystolepiota pulverulenta* (Huijsman) Vellinga

14) *Leucocoprinus cretaceus* (Bulliard: Fries) Locquin

15) *Leucocoprinus holospilotus* (Berkeley & Broome) Reid

16) *Leucocoprinus ianthinus* (Cooke) Locquin

17) *Leucocoprinus straminellus* (Baglietto) Narduci & Caroti

18) *Leucocoprinus submontagnei* Heinemann

19) *Leucocoprinus jubilaei* (Josserand) Wasser

20) *Leucoagaricus glabridiscus* (Sundberg) Wuilbaut

21) *Leucoagaricus rubrotinctus* (Peck) Singer

22) '*Lepiota viridiflava*' Petch (considered as a *Leucoagaricus* species in this treatise)

23) *Chlorophyllum abruptibulbum* (Heim) Vellinga

The following 26 species are new records to Kerala:

1) Lepiota metulaespora (Berkeley & Broome) Saccardo

2) *Lepiota castanea* Quelét

3) *Lepiota erythrosticta* (Berkeley & Broome) Saccardo

4) *Lepiota griseovirens* Maire

5) *Lepiota pseudoasperula* (Knudsen) Knudsen

6) *Lepiota brevipes* Murrill

7) *Lepiota elaiophylla* Vellinga & Huijser

8) *Lepiota ianthinosquamosa* Pegler

9) *Lepiota subincarnata* Lange

10) *Lepiota xanthophylla* Orton

11) *Lepiota plumbicolor* (Berkeley & Broome) Saccardo

12) *Lepiota murino-capitata* Dennis

13) *Cystolepiota cystidiosa* (Smith) Bon

14) *Cystolepiota pulverulenta* (Huijsman) Vellinga

15) *Leucocoprinus cretaceus* (Bulliard: Fries) Locquin

16) *Leucocoprinus holospilotus* (Berkeley & Broome) Reid

17) *Leucocoprinus ianthinus* (Cooke) Locquin

18) *Leucocoprinus straminellus* (Baglietto) Narduci & Caroti

19) *Leucocoprinus submontagnei* Heinemann

20) *Leucocoprinus jubilaei* (Josserand) Wasser

21) *Leucoagaricus glabridiscus* (Sundberg) Wuilbaut

22) *Leucoagaricus rubrotinctus* (Peck) Singer

23) '*Lepiota viridiflava*' Petch (considered as a *Leucoagaricus* species in this treatise)

24) *Macrolepiota dolichaula* (Berkeley & Broome) Rayner

25) *Chlorophyllum abruptibulbum* (Heim) Vellinga

26) *Chlorophyllum brunneum* (Farlow & Burt) Vellinga

Observations on fruiting behaviour and species abundance in Kerala revealed that the pattern of fruiting was highly irregular and inconsistent. Fruiting commenced in April and continued till November. Species of *Chlorophyllum*, *Leucoagaricus*, and *Leucocoprinus* were the first to fruit with the commencement of monsoon. *Leucocoprinus* species exhibited a comparatively more consistent fruiting pattern. *Lepiota* species fruited throughout the monsoon seasons, with a fruiting peak in the months of October and November. Species of *Lepiota* and *Leucocoprinus* showed a relatively high fruiting abundance and diversity.

Ancillary taxonomic observations made along with the floristic studies, involved the use of light and electron microscopes. Preliminary studies on cystidial and pileal ultrastructure carried out on a few representative lepiotaceous taxa indicated their potential to be developed as taxonomically informative subcellular markers in lepiotaceous fungi. The nature of cytoplasmic contents, organelles, and the granular matrix covering the cells

differed in the taxa studied. Differential staining with two different stains also indicated the uniqueness of each taxon examined. The presence of pseudoparaphyses in the hymenium of species belonging to *Leucocoprinus* is confirmed as a reliable morphological character to distinguish the genus from *Leucoagaricus*. Pseudoparaphyses were observed during the study to be distinct from normal basidia due to their differential staining by a mixture of Phloxine and Congo red, apart from their shape.

Light microscopic observation of the spores of *Lepiota viridiflava*, stained with cresyl blue indicated distinct metachromatism and this along with a few other characters of that taxon, suggests its transfer to the genus *Leucoagaricus*. Hence a new combination is warranted for this species. The collection of this species happened to be a rediscovery after about 90 years since its original publication. Neither a holotype nor any syntypes exist for this species in any of the world herbaria and hence a proposal for a neotype to be designated from the material collected during this study is suggested.

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2007

APPENDIX

Recipe for stains/reagents and buffers used:

1) Congo red (1 % aqueous solution)
   Congo red – 1 g
   Water – 99 ml

2) Cotton blue
   Phenol crystals – 20 g
   Lactic acid – 16 g
   Glycerol – 31 ml
   Water – 20 ml
   Cotton Blue crystals

3) Cresyl blue (1 % aqueous solution)

   Cresyl blue – 1 g
   Water – 99 ml

4) Glycol methacrylate (GMA)
   Infiltration solution:
      JB-4 solution A – 100 ml
      Benzoyl Peroxide, Plasticised (catalyst) – 1.25 g
   Embedding solution:
      Infiltration solution (fresh) – 25 ml
      JB-4 solution (accelerator) – 1 ml

5) Melzer's reagent
   Iodine crystals – 0.5 g
   Potassium iodide – 1.5 g
   Distilled water – 20 ml
   (Chloral hydrate, an ingredient of Melzer's reagent, has not been used because of the legal restrictions on its use in India)

6) Periodic Acid-Schiff's reagent
   a) Dimedone solution (2 g dimedone in 400 ml distilled water)
   b) 1 % Periodic acid
   c) Schiff's reagent (Pour 200 ml boiling distilled water over 1 g basic fuchsin. Shake well and cool to 50°C. Filter through course filter paper and add 30 ml of 1N HCl into a 250 ml flask. Cool to 25°C and add 2-3 g potassium metabisulphate. Let stand in the dark in a tightly stoppered bottle for 24 hours or until straw coloured. Add 0.5 g of activated charcoal, shake rapidly and filter through course filter paper. Repeat the last step

if the solution does not decolour. Reagent will be light yellow when ready for use.)

d) 0.5 % Sodium metabisulphite

7) Phloxine (1 % aqueous solution)

Phloxine – 1 g
Water – 99 ml

8) Quetol solution

Quetol 651 – 15 g
Nonenylsuccinic anhydride – 15 g
Nadic methyl anhydride – 15 g
Tri (dimethylaminoethyl)-phenol – 0.45 g

9) Sodium Cacodylate buffer

Solution A: (0.4 M)
Sodium cacodylate – 42.8 g
Distilled water – 500 ml
Solution B: (0.4 M)
Conc. HCl (36-38 %)
Distilled water – 50 ml

10) Toluidine blue

0.05 % Toluidine blue in benzoate buffer (Benzoic acid – 0.25 g, Sodium benzoate – 0.29 g, Water – 200 ml)

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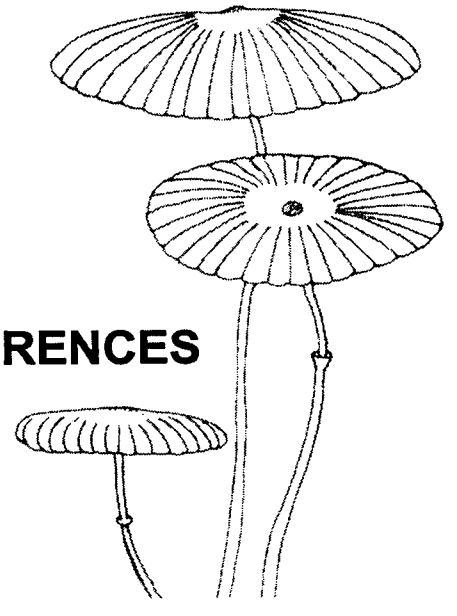

REFERENCES

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Aberdeen JEG, 1962. Notes on Australian *Lepiota* in the Kew Herbarium. *Kew Bulletin* 16: 129-137.

Agerer R, Iosifidou P, 2004. Rhizomorph structures of Hymenomycetes: A possibility to test DNA-based phylogenetic hypotheses. In Agerer R, Piepenbring M, Blanz P (eds), *Frontiers in Basidiomycote Mycology*. IHW-Verlag, Eching, pp. 249-302.

Akers BP, 2005. How do you solve a problem like *Lepiota*? *Mushroom the Journal of Wild Mushrooming* 23: 31-37.

Akers BP, Ovrebo CL, 2005. *Leucoagaricus bivelatus*, a new volvate lepiotoid species. *Mycotaxon* 91: 303-308.

Akers BP, Sundberg WJ, 1997. *Leucoagaricus hortensis*: some synonyms from Florida and taxonomic observations. *Mycotaxon* 62: 401-419.

Akers BP, Sundberg WJ, 1998. *Lepiotaceae* of Florida, I. *Lepiota* s. str., section *Ovisporae*. *Mycotaxon* 69: 429-436.

Akers BP, Sundberg WJ, 2000. *Lepiotaceae* of Florida, III. *Lepiota* s. str., section *Lepiota*. *Mycotaxon* 75: 137-145.

Akers BP, Angels SA, Kimbrough JW, 2000. *Leucoagaricus viridiflavoides*, a new species from Florida, with notes on related taxa. *Mycotaxon* 76: 39-50.

Arora D, 1986. *Mushrooms Demystified. A Comprehensive Guide to the Fleshy Fungi*, 2nd edn. Ten Speed Press, Berkeley.

Atkinson GF, 1914. The development of *Lepiota clypeolaria*. *Annales mycologici* 12: 346-356.

Atkinson GF, 1961. *Studies on American fungi Mushrooms edible, poisonous, etc.* Hafner Publishing Company, New York.

Babos M, 1958. Studies on Hungarian *Lepiota* species. I. Rare *Lepiota* species from the Hungarian central mountains. *Annales Historico-Naturales Musei Nationalis Hungarici* 50: 87-92.

Babos M, 1961. Studies on Hungarian *Lepiota* species. II. Rare *Lepiota* species. *Annales-Historico Naturales Musei Nationalis Hungarici Pars Botanica* 53: 195-199.

Babos M, 1969. Studies on Hungarian *Lepiota* species. III. Rare *Lepiota* species. *Annales Historico-Naturales Musei Nationalis Hungarici Pars Botanica* 61: 157-164.

Babos M, 1974. Studies on Hungarian *Lepiota* species. IV. Studies on Hungarian *Lepiota* s. l. species IV. *Annales Historico-Naturales Musei Nationalis Hungarici* 66: 65-75.

Babos M, 1979. The species of the 'Rubentes' group in the genus *Leucocoprinus. Beihefte zur Sydowia, Annales Mycologici* 8: 33-53.

Babos M, 1980. Studies on Hungarian *Lepiota* s. l. species V. *Annales Historico-Naturales Musei Nationalis Hungarici* 72: 81-90.

Babos M, 1981. Mycological examination of sawdust depots in Hungary. *Studia Botanica Hungarica* 15: 31-44.

Babos M, 1985. Studies on Hungarian *Lepiota* s.l. species. VI. Glasshouse species. *Agarica* 6 (12): 197-218.

Babos M, 1995. Studies on Hungarian *Lepiota* s.l. species. VII. *Documents Mycologiques* 98-100: 19-27.

Bas C, 1990. *Tricholomataceae* R. Heim ex Pouz. In: Bas C, Kuyper TW, Noordeloos ME, Vellinga EC (eds), *Flora agaricina neerlandica*. Vol. 2, Balkema, Rotterdam, The Netherlands, pp. 65-70.

Bas C, Kuyper TW, Noordeloos ME, Vellinga, EC, 1988. *Flora agaricina neerlandica*. Vol. 1. Balkema, Rotterdam, The Netherlands.

Beeli M, 1936. Genre *Lepiota* (Pers.) Fr.. *Flore iconographique des champignons du Congo* 2: 29-45.

Berkeley MA, Broome CE, 1870. The fungi of Ceylon. *Journal of the Linnean Society (Botany)* 11: 494-567.

Besl H, Mack P, Schmid-Heckel, H, 1984. New toxic fungi in the genera *Galerina* and *Lepiota*. *Zeitschrift fur Mykologie* 50: 183-192.

Bissi A, 1997. *Lepiota ochraceosulphurescens*. *Bolletino Gruppo Micologico G. Bresadola* 40: 113-118.

Bizzi A, Migliozzi V, 1994. Interesting or rare species of *Lepiotaceae*. 2 *Lepiota lepida* and *Lepiota clypeolarioides sensu* Kühner. *Micologia e Vegetazione Mediterranea* 9: 95-116.

Bodin M, Priou JP, 1994. Une nouvelle espece du littoral atlantique vendeen: *Lepiota saponella* nov. sp.). *Bulletin de la Societe Mycologique de France* 110: 125-137.

Boedijn KB, 1934. The genus *Chitoniella* with remarks on the genus *Chlorosporae*. *Bulletin du Jardin botanique de Buitenzorg* 13: 276-280.

Bon M, 1976. Lépiotes rares, critiques ou nouvelles aux dreilandertagung d'emmendingen, Septembre 1975. *Bulletin de la Societe Mycologique de France* 92: 317-334.

*Bon M. 1977. Les Lepiotes de l'herbier "Boudier" au Museum national d'Histoire naturelle de Paris. *Documents Mycologiques* 7: 11-22.

Bon M, 1985. Two interesting "Lepioteae:" from Norway. *Agarica* 12: 281-284.

Bon M, 1996. *Die Grosspilzflora von Europa. Lepiotaceae*. IHW-Verlag, Germany.

Bon M, Boiffard J, 1972. Lépiotes des dunes vendéennes. *Bulletin trimestrial de la Société mycologique de France*. 88: 15-28.

Bon M, Boiffard J, 1974. Lepiotes de vendee et de la cote atlantique française (1). *Bulletin de la Societe Mycologique de France* 90 (4): 287-306.

Britenbach, Kranzlin, 1995. *Fungi of Switzerland. Vol.* 4. *Agarics 2nd Part*. Mykologia Lucerne, Luzern.

Burlingham GS, 1945. Noteworthy species of *Lepiota* and *Lactaria*. *Mycologia* 37: 53-64.

Candusso M, Lanzoni G, 1990. *Lepiota s.l. Fungi Europaei 4*. Giovanna Biella, Saronno.

Cifuentes J, Guzmán G, 1982. Description and distribution of tropical fungi (*Agaricales*) unknown from Mexico. *Boletín de la Sociedad Mexicana Micologia* 16: 35-60.

Clémençon H, 1972. Die exkretorischen zystiden von *Baeospora myosura* (*Agaricales*). *Zeitschrift für Pilzkunde* 38: 55-71.

Clémençon H, 1972a. Die phaeozystiden von *Fayodia deusta* (*Agaricales*). *Zeitschrift für Pilzkunde* 38: 73-87.

Clémençon H, 1975. Ultrastructure of hymenial cells in two boletes. *Beihefte Nova Hedwigia* 51: 93-98.

Clémençon H, 1997. *Anatomie der hymenomyceten*. Flück-Wirth, *Teufen AG*.

Clémençon H, 2004. Cytology and plectology of the Hymenomycetes. *Bibliotheca Mycologica* 199: 1-488.

Contu M, 1991. Studi sulle *Lepiotaceae* – 1 alcune note sul genere *Sericeomyces* Heinem. In Sardegna. *Cryptogamie Mycologie* 12 (1): 1-12.

De Kok RPJ, Vellinga EC, 1998. Notulae ad floram agaricinum neerlandicam- XXXII *Macrolepiota*. *Persoonia* 17: 69-79.

Dennis RWG, 1952. *Lepiota* and allied genera in Trinidad, British West Indies. *Kew Bulletin*. 7: 459-499.

Dennis RWG, 1961. Fungi venezuelani: IV. *Agaricales*. *Kew Bulletin* 15: 67-156.

Dennis RWG, 1970. Fungus flora of Venezuela and adjoining countries. *Kew Bulletin Additional Series* 3: 54-57.

Didukh MY, Wasser SP, Nevo E, 2003a. Medicinal value of species of the family *Agaricaceae* Cohn (Higher basidiomycetes): Current stage of knowledge and future perspectives. *International Journal of Medicinal Mushrooms* 5: 133-152.

Didukh MY, Wasser SP, Nevo E, Yair U, 2003b. New records of *Leucocoprineae* and *Lepioteae* (Basidiomycotina, *Agaricales* s. l.) in Israel. *Documents Mycologiques* 32: 39-58.

Donk MA, 1962. The generic names proposed for *Agaricaceae*. *Beihefte zur Nova Hedwigia* 5: 1-320.

Dörfelt H, 1982. *Lepiota bettinae* – ein pteridophiler Warmhauspilz. *Zeitschrift für Mykologie* 48: 245-251.

Earle F S, 1909. The genera of North American gill fungi. *Bulletin of the New York Botanical Garden* 5: 373-451.

Enderle M, Krieglsteiner GJ, 1989. Die Gattung *Lepiota* (Pers.) S. F. Gray emend. Pat. In der Bundesrepublik Deutschland (Mitteleuropa). *Zeitschrift für Mykologie* 55: 43-103.

Esteve-Raventós F, Altés A, 1990. Tres interesantes Lepiotas tóxicas en la provincia de Madrid. *Boletín de la Sociedad Micologica de Madrid* 14: 161-168.

Esteve-Raventós F, Calonge FD, 1996. Two *Agaricales* rare and interesting in the Iberian Peninsula. *Boletín Sociedad Micologica de Madrid* 21: 293-298.

Feder N, O'Brien TP, 1968. Plant microtechnique: some principles and new methods. *American Journal of Botany* 55: 123-142.

Florence EJM, 2004. *Biodiversity documentation for Kerala* II: *Microorganisms* (*Fungi*). Kerala Forest Research Institute, Peechi.

Franco-Molano AE, 1999. A new species of *Macrolepiota* from Colombia. *Actualidades Biologicas* 21 (70): 13-17.

*Fries M, 1821. *Systema mycologicum.* Vol. 1. Lundae, Sweden.

Gadd GM, 2007. Geomycology: biochemical transformations of rocks, minerals, metals and radionuclides by fungi, bioweathering and bioremediation. *Mycological Research* 111: 3-49.

Ge ZW, Yang ZL, 2006. The genus *Chlorophyllum* (Basidiomycetes) in China. *Mycotaxon* 96: 181-191.

Ghosh RN, Pathak NC, 1965. The genus *Macrolepiota* in India. *Indian Phytopathology* 18: 360-362.

Ghosh RN, Pathak NC, Singh MS, 1976. The genus *Chlorophyllum* in India. *Indian Phytopathology* 29: 50-53.

Graph PW, 1927. The green-spored *Lepiota*. *Mycologia* 19: 322-326.

*Gray SF, 1821. *A Natural arrangement of British plants*. Baldwin, Cradock, and Joy, London.

Greuter W, Barrie FR, Burdet HM, Chaloner WG, Demoulin V, Hawksworth DL, Jørgensen PM, Nicolson DH, Silva PC, Trehane P, McNeill J, (eds), 1994. *International Code of Botanical Nomenclature* (Tokyo Code), Koeltz Scientific Books, Königstein.

*Gull K Newsam RJ, 1975. Ultrastructural organization of cystidia in the basidiomycete *Agrocybe praecox*. *Journal of General Microbiology* 91: 74-78.

Guzmán G, Guzmán-Davalos L, 1992. *A checklist of lepiotaceous fungi*. Koeltz Scientific Books, Champaign, Illinois.

Guzmán-Davalos L, Guzmán G, 1982. Contribution to the knowledge of the Lepiotaceae fungi from Quintana Roo (Mexico). *Boletín de la Sociedad Mexicana de Micologia*. 17: 43-53.

Haines JH, Lichstein E, Glickerman D, 1985. A fatal poisoning from an amatoxin containing *Lepiota*. *Mycopathologia* 93: 15-17.

Hawksworth DL, 1991. The fungal dimension of biodiversity: magnitude, significance and conservation. *Mycological Research* 95: 641-655.

Hawksworth DL, 1993. The relevance of mycology to development. *The African Journal of Mycology and Biotechnology*. 1: 1-11.

Hawksworth DL, Rossman AY, 1997. Where are all the undescribed fungi?. *Phytopathology* 87: 888-891.

Hawksworth DL, 2001. The magnitude of fungal diversity: the 1.5 million species estimate revisited. *Mycological Research* 105: 1422-1432.

Heim R, 1967. Etudes de mycologie centrafricaine II. La grande coulemelle d'Afrique équatoriale: *Leucocoprinus africanus* Heim, nov. sp. *Cahiers de la Maboké* 5: 63-66.

Heim R, 1969. Etudes de mycologie centrafricaine III. La coulemelle à bulbe trenchant d'Afrique centrale: *Leucocoprinus abruptibulbus* Heim, nov. sp. *Cahiers de la Maboké* 5: 15-20.

Heinemann P, 1968. Le genre *Chlorophyllum* Mass. (*Leucocoprineae*). Aperçu systématique et description des espèces congolaises. *Bulletin du Jardin Botanique National de Belgique* 38: 195-206.

Heinemann P, 1969. Le genre *Macrolepiota* Sing. (*Leucocoprineae*) au Congo-Kinshasa. *Bulletin du Jardin Botanique National de Belgique* 39: 201-226.

Heinemann P, 1973. *Leucocoprinus* nouvelles d'Afrique centrale. *Bulletin du Jardin Botanique National de Belgique* 43: 7-13.

Heinemann P, 1977a. *Leucocoprinus* nouvelles d'Afrique centrale II. *Bulletin du Jardin Botanique National de Belgique* 47: 83-86.

Heinemann P, 1977b. *Leucocoprinus*. Flore illustrée des champignons d'Afrique centrale. Fascicle 5. Meise.

Heinemann P, 1978. *Sericeomyces* genre nouveau *Leucocoprineae* (*Agaricaceae*). *Bulletin du Jardin Botanique National de Belgique* 48: 399-407.

Heinemann P, 1979. Deux nouveaux *Leucoagaricus* du Zaïre. *Bulletin du Jardin Botanique National de Belgique* 49: 461-462.

Heinemann P, 1980. *Leucocoprineae, pp (Agaricaceae) Flore illustrée des champignons d'Afrique centrale*. Fascicle 7. Meise.

Heinemann P, 1981. *Flore illustrée des champignons d'Afrique centrale*. Fascicle 7. Meise.

Heinemann P, 1989. La trame des *Macrolepiota*. *Bulletin de la Société mycologique de France*. 105: 29-33.

Hemmes DE, Desjardin DE, 2002. *Mushrooms of Hawaii: an identification guide*. Ten Speed Press, Berkeley, California.

Hongo T, 1976. Agarics from Papua-New Guinea (1). *Memoirs of the Faculty of Education, Shiga University. Natural Science* 26: 26-35.

Horak E, 1980a. Fungi Agaricini Novazelandiae IX. *Lepiotula* (Maire) Locquin ex Horak. *New Zealand Journal of Botany* 18: 183-188.

Horak E, 1980b. On Australasian species of *Lepiota* S. F. GRAY (*Agaricales*) with spurred spores. *Sydowia* 33: 111-144.

Huijsman HSC, 1960. Observations sur les *Lepioteae* Fayod. *Persoonia* 1: 325-329.

Huijsman HSC, 1962. Sur le probléme *Lepiota helveola* Bres. *Persoonia* 2: 355-370.

Imai S, 1941. Studia Agaricacearum Japanicarum. II. *The Botanical Magazine* 55: 444-452.

Johnson J, 1999. Phylogenetic relationships within *Lepiota sensu lato* based on morphological and molecular data. *Mycologia* 91: 443-493.

Johnson J, Vilgalys R, 1998. Phylogenetic systematics of *Lepiota sensu lato* based on nuclear large subunit rDNA evidence. *Mycologia* 90: 971-979.

Kauffman CH, 1924. The genus *Lepiota* in United States. *Papers from the Michigan Academy of Science, Arts and Letters* 4: 311-344.

Kelderman PH, 1988a. New and very rare Dutch *Lepiota* species. *Coolia* 31: 12-17.

Kelderman PH, 1988b. New and very rare *Lepiota* species II. *Coolia* 31: 38-44.

Kelderman PH, 1988c. New and very rare *Lepiota* species III. *Coolia* 31: 89-93.

Kelderman PH, 1989. New and very rare species of *Lepiota* in the Netherlands. *Coolia* 34: 67-70.

Kelderman PH, 1991a. New and very rare *Lepiota* species from Netherlands. *Coolia* 34: 52-55.

Kelderman PH, 1991b. New and very rare species of *Lepiota* in the Netherlands. *Coolia* 34: 80-87.

Kelderman PH, 1992. New and very rare Dutch *Lepiota* species (VII). *Coolia* 34: 76-82.

Kelderman PH, 1994. *Lepiota cingulum* spec. nov., a new species in section *Stenosporae*. *Persoonia* 15: 537-540.

Kirk PM, Cannon PF, David JC, Stalpers JA, 2001. *Dictionary of the fungi. Ed.* 9. CABI publishing, Wallingford, Oxon, UK.

Kleven NL, McLaughlin DJ, 1989. A light and electron microscopic study of the developmental cycle in the basidiomycete *Pachnocybe ferruginea*. *Canadian Journal of Botany* 67: 1336-1348.

Knudsen H, 1978. Notes on *Cystolepiota* Sing. and *Lepiota* S. F. Gray. *Botanisk Tidsskrift* 73: 124-136.

Knudsen H, 1980. A revision of *Lepiota* sect. *Echinatae* and *Amyloideae* (*Agaricaceae*) in Europe. *Botanisk Tidsskrift* 75: 121-155.

Kornerup A, Wanscher JH, 1978. *Methuen handbook of colour*, 3rd edn. Methuen, London.

Korf RP, 2005. Reinventing taxonomy: a curmudgeon's view of 250 years of fungal taxonomy, the crisis in biodiversity, and the pitfalls of the phylogenetic age. *Mycotaxon* 93: 407-415.

Kost G, 2004. Ecology and morphology of some tropical fungi (Contributions to tropical fungi II). In: Agerer R, Piepenbring M, Blanz P, (eds), *Frontiers in Basidiomycote Mycology*. IHW-Verlag, Eching, pp. 387-396.

Krieglsteiner GJ, 1981. Die gattung *Macrolepiota* Singer in der Bundesrepublik Deutschland (Mitteleuropa). *Zeitschrift fur Mykologie* 47: 81-89.

Krieglsteiner GJ, 1982. Über einige neue, seltene, kritische Makromyzeten in der Bundesrepublik Deutschland III. *Zeitschrift fur Mykologie* 48: 43-64.

Kühner R, 1936. Researches sur le genre *Lepiota*. *Bulletin de la Société Mycologique de France* 52: 175-235.

Kühner R, 1983. *Agaricales* de la zone alpine. Genre *Lepiota* (Pers.: Fr.) Gray. *Cryptogamie, Mycologie* 4: 61-69.

Kühner R, Romagnesi H, 1953. *Flore analytique des champignons supérieurs (Agarics, Boletes, Chanterelles)*. Masson, Paris.

Kumar TKA, Manimohan P, 2004. A new species of *Leucocoprinus* from India. *Mycotaxon* 90 (2): 393-397.

Kuyper TW, 1988. Specific and infraspecific delimitation. In Bas C, Kuyper TW, Noordeloos ME, Vellinga EC (eds), *Flora agaricina neerlandica*. Vol. 1: 30-37, Rotterdam.

Lange JE, 1915. Studies in the agarics of Denmark II. The genus *Lepiota*. *Dansk Botanisk Arkiv*. 2(3): 13-31.

Lange C, 1995. The genus *Leucoagaricus* in Denmark: distribution and ecology. *Documents Mycologiques* 25 (98): 249-256.

Largent DL, 1977. *How to identify mushrooms to genus* I: *Macroscopic features*. Mad River Press Inc, Eureka, USA.

Leelavathy KM, Zachariah S, Sankaran KV, 1981. *Clarkeinda trachodes*- an agaric new to India. *Mycologia* 73: 204-207.

*Lentz PL, 1971. Analysis of modified hyphae as a tool in taxonomic research in the higher basidiomycetes. In: Petersen RH, (ed.), *Evolution of the higher Basidiomycetes*. University of Tennessee Press, Knoxville, TN, USA, pp. 99-127.

Locquin M, 1945a. Les Lépiotes communes ou remarquables de la région Lyonnaise. *Bulletin mensuel de la Société Linnéenne de Lyon* 14: 10-12, 14-16, 18-23.

Locquin M, 1945b. Notes sur les Lépiotes II. *Bulletin mensuel de la Société Linnéenne de Lyon* 14: 82-100.

Locquin M, 1951. Les espéces françaises du genre *Leucocoprinus* Premiére partie: section *Procerae*. *Revue de mycologie* 16: 213-234.

Locquin M, 1952. Les espéces françaises du genre *Leucocoprinus* Premiére partie: section *Procerae* (suite). *Revue de mycologie* 17: 46-54.

Malysheva EF, 2005. *Lepiota pseudoasperula* (*Agaricaceae*), new to Russia. *Mycotaxon* 91: 365-368.

Manjula B, 1983. A revised list of the agaricoid and boletoid basidiomycetes from India and Nepal. *Proceedings of the Indian Academy of Sciences* (*Plant Sciences*) 92: 81-213.

Manimohan P, Vrinda KB, Leelavathy KM, 1988. Rare agarics from Southern India, *Kavaka* 16: 50-56.

Massee GE, 1898. *Chlorophyllum*. *Kew Bulletin*: 135-136.

May TW, Wood AE, 1997. *Fungi of Australia. Volume 2A. Catalogue and bibliography of Australian macrofungi* 1. *Basidiomycota*. Australian Biological Resources Study. Canberra.

McLaughlin DJ, 1974. Ultrastructural localization of carbohydrate in the hymenium and subhymenium of *Coprinus*. *Protoplasma* 82: 341-364.

Migliozzi V, 1986. *Leucocoprinus cepaestipes* (Sow.: Fr.) Pat. forma *macrosporus* fo. nov., *Leucocoprinus cretatus* Locquin ed uno sguardo alla stirpe *cepaestipes*. *Bolletino dell' Associazione Micologica ed Ecologica Romana* 6/7: 6-19.

Migliozzi V, 1997. Il complesso *Lepiota helveola* negli erbari trentini di G. Bresadola. *Bolletino Del Gruppo Micologico G. Bresadola* 40:327-336.

Migliozzi V, Perrone L, 1982. Sulle Lepiotee - 2° Contributo *Leucoagaricus pilatianus* (Demoulin) Bon & Boiffard. *Bolletino dell' Associazione Micologica ed Ecologica Romana* 18: 25-33.

Migliozzi V, Coccia M, 1982. *Lepiota bettinae* Dörfelt 1982. *Bolletino dell' Associazione Micologica ed Ecologica Romana* 18: 5-11.

Migliozzi V, Brunori A, Coccia M, 1989a. La micoflora delle Serre di S. Sisto Vecchio in Roma Lepiotee. 1ª parte. *Revista di micologia, Associazione Micologica Bresadola* 32 (1-2): 5-29.

Migliozzi V, Brunori A, Coccia M, 1989b. La micoflora delle Serre di S. Sisto Vecchio in Roma Lepiotee. 2ª parte. *Revista di micologia, Bollettino Associazione Micologica Bresadola* 32 (3-4): 99-111.

Migliozzi V, Resta G, 2000. Note sulla sottosezione *pilatiani* del genere *Leucoagaricus*. Due nuove varieta*: Leucoagaricus pseudopilatianus* var. *rugosoreticulatus* e *Leucoagaricus pseudopilatianus* var. *roseodiffractus*. *Micologia e Vegetazione Mediterranea* 15 (2): 129-156.

Miller OK Jr, Volk TJ, Bessette AE, 1996. A new genus, *Leucopholiota*, in the *Tricholomataceae* (*Agaricales*) to accommodate an unusual taxon. *Mycologia* 88: 137-139.

Mims CW, Celio GJ, Richardson EA, 2003. The use of high pressure freezing and freeze substitution to study host-pathogen interactions in fungal diseases of plants. *Microscopy and Microanalysis* 9: 522-531.

Möller FH, 1958. Two *Lepiota* species hitherto misinterpreted in Denmark. *Friesia* 6: 20-25.

Moncalvo JM, Vilgalys R, Redhead SA, Johnson JE, James TY, Aime MC, Hofstetter V, Verduin SJW, Larsson E, Baroni TJ, Thorn RG, Jacobsson S, Clémençon H, Miller OK jr, 2002. One hundred and seventeen clades of euagarics. *Molecular Phylogenetics and evolution* 23: 357-400.

Montoya L, Bandala VM, 2005. A new species and a new record of *Lepiota* occurring in the Gulf of Mexico area. *Mycotaxon* 94: 111-125.

Moreno G, Bañares A, Heykoop M, 1995. *Macrolepiota molybdites* (Meyer: Fries) *comb. nov.*, new to the Canary Islands. *Mycotaxon* 55: 467-471.

Morgan AP, 1906. North American species of *Lepiota*. *Journal of Mycology* 12: 154-159.

Morgan AP, 1907. North American species of *Lepiota*. *Journal of Mycology* 13: 1-18.

Moser M, 1983. *Keys to agarics and boleti*. Roger Phillips, London.

Mossebo DC, Amougou Akoa, Atangana Étémé R, 2000. *Macrolepiota globosa* et *Nothopanus nsimalenensis*, deux nouvelles espéces fongiques du Cameroun. *Mycotaxon* 76: 267-278.

Mueller UG, 2002. Ant versus fungus versus mutualism: ant-cultivar conflict and the deconstruction of the attine ant-fungus symbiosis. *The American Naturalist* 160: S67-S98.

Mueller UG, Rehner S, Schultz TR 1998. The evolution of Agriculture in ants. *Science* 281: 2034-2038.

Murrill WA, 1911. The *Agaricaceae* of tropical North America, II. *Mycologia* 3: 79-91.

Murrill WA, 1912. The *Agaricaceae* of the Pacific coast-II. *Mycologia* 5: 231-262.

Murrill WA, 1914. Agaricales, *Agaricaceae*. *North American flora* 10: 1-76.

Murrill WA, 1942. New fungi from Florida. *Lloydia* 5:136-157.

Murrill WA, 1943. More new fungi from Florida. *Lloydia* 6: 207-228.

Murrill WA, 1944. More fungi from Florida. *Lloydia* 7: 303-327.

Murrill WA, 1946. New and interesting Florida fungi. *Lloydia* 9: 315-331.

Murrill WA, 1949. Florida Lepiotas. *Lloydia* 12: 56-61.

Murrill WA, 1951. New agarics from Florida. *Mycologia* 43: 235-239.

Natarajan K, Manjula B, 1983. South Indian *Agaricales* XII. *Lepiota*. *Biblotheca Mycologica* 91: 563-581.

Natarajan K, Raman N, 1983. South Indian *Agaricales*. *Bibliotheca Mycologica* 89: 1-203.

Natarajan K, Kumaresan V, Narayanan K, 2005. A checklist of Indian agarics and boletes. *Kavaka* 33: 61-128.

Negi SS, 1994. *India's forests, forestry and wildlife*. Indus Publishing Company, New Delhi.

Orton PD, 1960. New check list of British Agarics and Boleti. III. Notes on the genera and species in the list. *Transactions of the British Mycological Society* 43: 159-439.

*Pattouillard N, 1888. Quelques points de la classification des Agaricineés. *Journal de Botanique, Paris.*: 12-16.

Pázmány D, 1985. Die *Macrolepiota*: Arten in Transsilvanien (Rumänien). *Zeitschrift fur Mykologie* 51 (1): 51-60.

Pearson AA, 1950. Cape agarics and boleti. *Transactions of the British Mycological Society* 33: 276-316.

Pearson AA, 1952. New records and observations. V. *Transactions of the British Mycological Society* 35: 97-122.

Pegler DN, 1963. A species of *Lepiota* new to Britain. *Kew Bulletin* 16: 477-479.

Pegler DN, 1969. Studies on African *Agaricales*: II. *Kew Bulletin* 23: 219-222.

Pegler DN, 1972. A revision of the genus *Lepiota* from Ceylon. *Kew Bulletin* 27: 155-202.

Pegler DN, 1975. A revision of the Zanzibar *Agaricales* described by Berkeley. *Kew Bulletin* 30: 429-442.

Pegler DN, 1977. A Preliminary Agaric Flora of East Africa. *Kew Bulletin Additional Series* 6: 1-615.

Pegler DN, 1983. Agaric Flora of the Lesser Antilles. *Kew Bulletin Additional Series* 9: 1-668.

Pegler DN, 1985. The genus *Clarkeinda* (Basidiomycotina: *Agaricaceae). Botanical Journal of the Linnean Society* 91: 245-252.

Pegler DN, 1986. Agaric Flora of Sri Lanka. *Kew Bulletin Additional Series* 12: 1-519.

Pegler DN, 1988. A revision of the *Agaricales* of Cuba 3. Keys to families, genera and species. *Kew Bulletin* 42: 68-69.

Pegler DN, Young TWK, 1971. Basidiospore morphology in the *Agaricales*. *Beihefte zur Nova Hedwigia* 35: 1-200.

Peintner U, Horak E, 1999. *Lepiota* and *Cystolepiota* (*Agaricales*) in Arctic-alpine habitats. *Osterreichische Zeitschrift fur Pilzkunde*. 8: 19-34.

*Persoon CH, 1794. Neuer Versuch einer systematischen Eintheilung der Schwämme. *Neues Magazin für der Botanik* 1: 63-128.

*Persoon CH, 1797. *Tentamen dispositiois methodicae fungorum*. Leipzig.

*Persoon CH, 1801. *Synopsis Methodica Fungorum*. Gottingen, Germany.

Petch T, 1908. The genus *Chitoniella*. *Chitoniella podores* (Berk. & Br.), P. Henn. *Annals of the Royal Botanic Gardens*, Peradeniya 4 (4): 113-122.

Petch T, 1910. Revision of Ceylon fungi (Part II). *Annals of the Royal Botanic Garden*, Peradeniya 4: 373-444.

Petch T, 1917. Additions to Ceylon fungi. *Annals of the Royal Botanic Garden*, Peradeniya 5: 195-256.

Rauschert S, 1986. Proposal to conserve the generic name *Lepiota* (Pers.) S. F. Gray (Fungi) with a typus conservandus. *Taxon* 35: 738-740.

Rea C, 1922. *British Basidiomycetes*. Cambridge University Press, Cambridge.

Reid DA, 1958. New or interesting records of British hymenomycetes. II. *Transactions of the British Mycological Society* 41: 419-445.

Reid DA, 1989. Notes on some leucocoprinoid fungi from Britain. *Mycological Research* 93 (40): 413-423.

Reid DA, 1990. The *Leucocoprinus badhami* complex in Europe: species which redden on bruising or become green in ammonia fumes. *Mycological Research* 94: 641-670.

Reid DA, 1995. Observations on *Leucoagaricus melanotrichus* and similar species. *Mycotaxon* 53: 325-336.

Reid DA, 1997. *Macrolepiota fuligineosquarrosa* from Britian. *Bolletino Gruppo Micologico G. Bresadola* 40: 399-404.

Reid DA, 1998. The nomenclature and taxonomy of *Leucoagaricus pinguipes* and *L. macrorhizus* with a description of a recent British collection of *L. pinguipes*. *Mycotaxon* 69: 117-128.

Reid DA, Eicker A, 1993a. South African fungi. 2. Some species of *Leucoagaricus* and *Leucocoprinus*. *South African Journal of Botany* 59: 85-97.

Reid DA, Eicker A, 1993b. South African fungi 3. A reinvestigation of Pearson's *Lepiota* types. *South African Journal of Botany* 59: 410-424.

Reid DA, Pegler DN, Spooner BM, 1981. An annotated list of the fungi of the Galapagos islands. *Kew Bulletin* 35: 847-892.

Reijnders AFM, 1975. The development of three species of the *Agaricaceae* and the ontogenetic pattern of this family as a whole. *Persoonia* 8: 307-319.

Rexer KH, Kost G, 1989. Zur systematic der agaricoiden hymenomyceten II. Verwandschaftliche beziehungen von *Megacollybia*, *Oudmansiella*, *Strobilurus* zu anderen Basidiomyceten, nebst studien zur ultrastruktur ihrer cystiden. *Zeitschrift für Mykologie* 55: 241-252.

*Ricken A, 1914. *Die Blatterpilze Deutschlands*. Leipig.

Rowley CR, Moran DT, 1975. A simple technique for mounting wrinkle-free sections on formvar-coated slot grids. *Ultramicrotomy* 1:151–155.

Sathe AV, 1980. Introduction. In In *Agaricales* (mushroom) of South West India, Monograph 1: 7. *Maharashtra Association for the Cultivation of Science, Research Institute.*

*Sathe AV, Sasangan KC, 1977. *Agaricales* from South west India III. *Biovigyanam* 3: 119-121.

Sathe AV, Daniel J, 1980. *Agaricales* (Mushrooms) of Kerala State. In *Agaricales* (mushroom) of South West India, Monograph 1: 75-108. *Maharashtra Association for the Cultivation of Science, Research Institute.*

Sathe AV, Kulkarni SM, 1980. *Agaricales* (Mushrooms) of Karnataka State. In *Agaricales* (mushroom) of South West India, Monograph 1: 43-73. *Maharashtra Association for the Cultivation of Science, Research Institute.*

Sato T, 1968. A modified method for lead staining of thin sections. *Journal of Electron Microscopy* 17: 158-159.

Schulz-Weddigen I, 1986. Contributions to the knowledge of the genus *Lepiota*. I. A case of intoxication caused by *Lepiota brunneo-incarnata* in North Western Germany. *Zeitschrift fur Mykologie* 52: 91-100.

Setliff EC, 1979. Light and electron microscopic studies of cystidia in *Phanerochaete chrysosporium*. *Mycologia* 71: 1244-1247.

Singer R, 1948a. Diagnoses fungorum novorum Agaricalium. *Sydowia* 2: 26-48.

Singer R, 1948b. New and interesting species of Basidiomycetes II. *Papers from the Michigan Academy of Science, Arts and Letters*. 32: 141.

*Singer R, 1951. The *Agaricales* (Mushrooms) in modern taxonomy. *Lilloa* 22: 1-832.

Singer R, 1969. Mycoflora Australis. *Beihefte Nova Hedwigia* 29: 160-172.

Singer R, 1972. Cyanophilous spore walls in the *Agaricales* and agaricoid basidiomycetes. *Mycologia* 64: 822-829.

Singer R, 1986. *The Agaricales in modern taxonomy*. 4th edn. Koeltz Scientific Books, Koenigstein.

*Singer R, Clemençon, H. 1972. Notes on some leucosporous and rhodosporous European agarics. *Nova Hedwigia* 23: 305-344.

Singer R, Digilo APL, 1952 Prodromo de la flora agaricina Argentina. *Lilloa* 25: 281.

Singer R, Smith AH, 1946. Proposals concerning the nomenclature of gill fungi including a list of proposed lectotypes and genera conservanda. *Mycologia* 38: 240-299.

Smith HV, 1954. A revision of the Michigan species of *Lepiota*. *Lloydia* 17 (4): 307-328.

Smith HV, 1965. Contributions toward a monograph on the genus *Lepiota*, I. Type studies in the genus *Lepiota*. *Contributions from the University of Michigan Herbarium* 28: 97-117.

Smith HV, 1981. Some species of *Leucocoprinus* which grow in greenhouses. *The Michigan Botanist* 20: 45-52.

Smith AH, Rea PM, 1944. Fungi of Southern California – II. *Mycologia* 36: 125-137.

Smith HV, Sundberg WJ, 1979. Studies on the *Lepiotaceae* of the Pacific Coast Region. I. Two new species. *Mycotaxon* 8: 446-452.

Smith HV, Weber NS, 1982. Selected species of *Leucocoprinus* from the southeastern United States. *Contributions from the University of Michigan Herbarium* 15: 297-309.

Strack BA, Sundberg WJ, 1981. Notes on cystidial development in *Pluteus cervinus* (*Agaricales*). *Nova Hedwigia* 35: 537-551.

Subramanian CV, 1982. Tropical mycology: future needs and development. *Current Science* 51: 321-323.

Subramanian CV, 1992. Tropical mycology and biotechnology. *Current Science* 63: 167-172.

Sundberg WJ, 1971a. A new species of *Lepiota*. *Mycologia* 53: 79-82.

Sundberg WJ, 1971b. The genus *Chlorophyllum* (*Lepiotaceae*) in California. *Madroño* 21: 15-20.

Sundberg WJ, 1976. *Lepiota sensu lato* in California. II. Type studies of *Lepiota cuppressea* and *Lepiota marginata*. *Mycotaxon* 3: 381-386.

Sundberg WJ, 1989. *Lepiota sensu lato* in California. III. Species with a hymeniform pileipellis. *Mycotaxon* 34: 239-248.

Thaler I, Gailhofer M, 1981. Die Feinstruktur der chrysocystiden von *Hypholoma fasciculare* (*Basidiomycetes*, *Agaricales*). *Protoplasma* 108: 289-300.

*Thielke C, 1972. Zisternenaggregate bei höheren Pilzen. *Protoplasma* 75: 335-339.

Thielke C, 1978. Feinstrukturen bei Basidiomyceten. *Zeitschrift für Mykologie* 44: 71-89.

Thielke C, 1982. Membranaggergate und Filamente in den Zystiden von *Volvariella bombycina*. *Zeitschrift für Mykologie* 49: 257-264.

Urbonas V, Kalamees K, Lukin V, 1986. *Conspectus florum Agaricalium fungorum* (*Agaricales s. l.*) Lithuaniae, Latviae et Estoniae, Vilnius " Mokslas".

Vellinga EC, 1992. Notulae ad floram agaricinam neerlandicam – XVIII. Some notes on *Cystolepiota* and *Lepiota*. *Persoonia* 14: 407-415.

Vellinga EC, 2000a. Notes on *Lepiota* and *Leucoagaricus*- Type studies on *Lepiota magnispora*, *Lepiota barssii*, and *Agaricus americanus*. *Mycotaxon* 76: 429-438.

Vellinga EC, 2000b. Notulae ad floram agaricinam neerlandicam – XXXVIII. *Leucoagaricus* subgenus *Sericeomyces*. *Persoonia* 17: 473-480.

Vellinga EC, 2001a. *Lepiota*. In Noordeloos ME, Kuyper Th. W, Vellinga EC, (eds.). *Flora agaricina neerlandica* 5: 21, 109-151. A. A. Balkema Publishers, Lisse.

Vellinga EC, 2001b. *Leucoagaricus*. In Noordeloos ME, Kuyper Th. W, Vellinga EC, (eds.). *Flora agaricina neerlandica* 5: 85-108. A. A. Balkema Publishers, Lisse.

Vellinga EC, 2001c. *Leucocoprinus*. In Noordeloos ME, Kuyper Th. W, Vellinga EC, (eds.). *Flora agaricina neerlandica* 5: 76-84. A. A. Balkema Publishers, Lisse.

Vellinga EC, (2001d). *Macrolepiota*. In Noordeloos ME, Kuyper Th. W, Vellinga EC, (eds.). *Flora agaricina neerlandica* 5: 64-73. A. A. Balkema Publishers, Lisse.

Vellinga EC, 2001e. *Chlorophyllum*. In Noordeloos ME., Kuyper Th. W, Vellinga EC. (eds.). *Flora agaricina neerlandica* 5: 74-75. A. A. Balkema Publishers, Lisse.

Vellinga EC, 2001f. *Cystolepiota*. In Noordeloos ME, Kuyper Th. W, Vellinga EC (eds.). *Flora agaricina neerlandica* 5: 154-160. A. A. Balkema Publishers, Lisse.

Vellinga EC, 2001g. *Macrolepiota*, *Chlorophyllum*, *Leucocoprinus*, *Leucoagaricus*, *Lepiota*, *Cystolepiota*. In Noordeloos ME, Kuyper Th.

W, Vellinga EC (eds.). *Flora agaricina neerlandica* 5: 64-151 & 154-160. A. A. Balkema Publishers, Lisse.

Vellinga EC, 2002. New combinations in *Chlorophyllum*. *Mycotaxon* 83: 415-417.

Vellinga EC, 2003a. Phylogeny of *Lepiota* (*Agaricaceae*) – Evidence from nrITS and nrLSU sequences. *Mycological Progress* 2(4): 305-322.

Vellinga EC, 2003b. Type studies in *Agaricaceae- Chlorophyllum rachodes* and allies. *Mycotaxon* 85: 259-270.

Vellinga EC, 2003c. *Chlorophyllum* and *Macrolepiota* (*Agaricaceae*) in Australia. *Australian Systematic Botany* 16: 361-370.

Vellinga EC 2004a. Genera in the family *Agaricaceae*: evidence from nrITS and nrLSU sequences. *Mycological Research* 108(4): 354-357.

Vellinga EC, 2004b. Ecology and distribution of lepiotaceous fungi. *Nova Hedwigia* 78: 273-299.

Vellinga EC, 2006. *Nomenclatural Overview of Lepiotaceous Fungi*. Version 2.1. available online at http://plantbio.berkeley.edu/~bruns/ev/vellinga_feb2006_nomencl_v21.pdf.

Vellinga EC, Huijser HA, 1993. Notulae ad Floram Agaricinam Neerlandicam 21- *Lepiota* section. *Stenosporae*. *Persoonia* 15 (2): 223-240.

Vellinga EC, Huijser HA, 1997. *Lepiota xanthophylla* and its green house counterpart. *Bolletino Del Gruppo Micologico G. Bresadola* 40:457-464.

Vellinga EC, Huijser HA, 1998. Notes on *Cystolepiota*: sections *Cystolepiota* and *Pulverolepiota*. *Persoonia* 16: 513-526.

Vellinga, EC De Kok RPJ, 2002. Proposal to conserve the name *Chlorophyllum* Massee against *Endoptychum* Czern. (*Agaricaceae*). *Taxon* 51: 563-564.

Vellinga EC, Yang ZL, 2003. *Volvolepiota* and *Macrolepiota- Macrolepiota velosa*, a new species from China. *Mycotaxon* 85: 183-186.

Vellinga EC, Franco-Molano, A. E. & Bas, C. (1998) Studies in *Lepiota* II. – *Lepiota rubella*. Sydowia 50: 272-277.

Vellinga EC, de Kok RPJ, Bruns TD, 2003. Phylogeny and taxonomy of *Macrolepiota* (*Agaricaceae*). *Mycologia* 95: 442-456.

Vrinda KB, Pradeep CK, Mathew S, Abraham TK, 1997. *Agaricales* from Western Ghats – IV. *Journal of Mycology and Plant Pathology* 27 (3): 346-350.

Vrinda KB, Pradeep CK, Mathew S, Abraham TK, 1999. *Agaricales* from Western Ghats – VII. *Mushroom Research* 8: 9-12.

Vrinda KB., Pradeep CK, Abraham TK, 2001. Additions to Indian mushroom flora. *Mushroom Research* 10: 1-4.

Vrinda KB, Pradeep CK, Deepa S, Abraham TK, 2003. Some leucocoprinoid fungi from the Western Ghats. *Mushroom Research* 12: 1-7.

Wang HC, Yang ZL, 2005. A new species of *Lepiota* (*Agaricaceae*, Basidiomycetes) from China. *Mycotaxon* 94: 51-54.

Wasser SP, 1993. *Tribes Cystodermateae Sing. and Leucocoprineae Sing. of the CIS and Baltic States*. Libri Botanici 9: 1-105.

Wasser SP, 2002. *Biodiversity of Cyanoprocaryotes, Algae and Fungi if Israel. Family Agaricaceae (Fr.) Cohn of Israel mycobiota*. Vol. I. *Tribe Agariceae Pat.* A. R. A. Gantner Verlag, Ruggell.

Waterkeyn L, Bienfait A, Monniez T, 1992. Les cystides à cristaux des *Inocybes* (*Agaricales*) etude histochimique et cristallographique. *Canadian Journal of Botany* 70: 910-920.

Weresub LK, 1971. Congo red for instant distinction between poisonous *Lepiota molybdites* and edible *L. brunnea*. *Canadian Journal of Botany* 49: 2059-2060.

Zeller SM, 1934. A new species of *Lepiota*. *Mycologia* 26: 210-211.

* Original not seen.

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