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Studies on Coprophilous Agaricoid Mushrooms: An Appraisal

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ABSTRACT

The present paper is an attempt to review and provide systematic information about the ecology, diversity, distribution and human relevance of wild coprophilous mushrooms the world over. The information provided herein is derived from a study carried out in the state of Punjab in India and records contained in more than 125 authentic monographic publications and research articles throughout the world. During the survey from the years 2007 to 2011in Punjab state, a total number of 172 collections have been observed, growing as saprobes on dung of various domesticated and wild herbivorous animals in pastures, open areas, zoological parks, and on dung heaps along roadsides or along village ponds, etc. High coprophilous mushrooms' diversity has been established and a number of rare and sensitive species were recorded during the study. Also while analysing the relevant references related to coprophilous mushrooms and their ecological places it was noted that dung is an important substrate which serves as a favorable niche for the growth of a variety of mushrooms throughout the world. The present paper aims to create awareness for conservation of the fascinating world of coprophilous fungi in their natural habitats. The status and taxonomic placement of each taxon in this review is updated as per MycoBank Database. The paper can serve as base line information and indicator for further mycological studies in India as well as in other countries with similar scenarios.

Keywords: *Agaricomycetes*, *Basidiomycota*, biodiversity, dung, mushrooms, distribution

INTRODUCTION

Fungi grow everywhere and in all sorts of habits and habitats. The saprotrophic fungi are the primary agents responsible for decomposition of organic matter. These fungi bring about spoilage of food and damage fabrics, paper, leather and other organic matter. They also grow on dung of all kinds of animals (Dix and Webster, 1995). In scientific terms the 'dung-loving' fungi are known as 'coprophilous' or 'fimicolous'. They represent a diverse community of morphologically and physiologically specialized mycota which provide a biological force for the decomposition and recycling of animal faeces (Richardson, 2008). The world over studies on coprophilous fungi suggests that this group plays an important role in carbon flow, ecosystem energetics and in the formation of soil (Halfter and Matthew, 1971; Angel and Wicklow, 1974, 1975; Kumar *et al.*, 1995). They possess a wide variety of adaptive characteristics that assist their survival and reproduction on dung. These characteristics include the phototrophic nature of the spore-producing structures, adhesive projectiles of their spores enabling attachment to the herbages, pigmentation in spores which provide protection against UV exposure and the resistance of their spores to digestive enzymes and acids in the animal gut (Dix and Webster, 1995; Richardson, 2008). The undigested carbohydrates, hemicelluloses and lignin, along with amino acids, vitamins, growth factors and minerals in the dung, aid their colonization and growth (Kumar *et al.,* 1995). The physical structure of dung, its pH value and high moisture contents are reported to be the major contributing factors for its suitability as a fungal substratum (Morrison 1959; Lodha, 1974).

Coprophilous fungi belong to wide range of taxonomic groups including *Acrasiales*, *Mycetozoa*, *Mucorales*, *Pezizales*, *Sordariales*, *Coprinaceae* and some other basidiomycetous fungi (Kirk *et al.*, 2008). The present review, however, has been focused on the diversity and distribution of lamellate basidiomycetous coprophilous macrofungi belonging to the order *Agaricales* (Singer, 1986; Kirk *et al.,* 2008).

Coprophilous mushrooms are reported to occur more frequently on dung of herbivores than carnivores. The dung of meat-eating animals being quite rich in proteins possesses bacteria and some insects which plays a pivotal role in decomposition (Bell, 1983; Richardson, 2001b). As compared in herbivorous dung much of the content is cellulose and lignin which are mostly decomposed by basidiomycetous fungi as bacteria cannot decompose these complex substances. Coprophilous mushrooms have seldom been documented on reptilian or amphibian dung, indicating that coprophily in fungi might have developed among the warm-blooded animals (Webster, 1970). Some of the common dung addicts as documented by Arora (1986) include *Agaricus bisporus* (J.E. Lange) Imbach, *Agrocybe pediades* (Pers.:Fr.) Fayod, *Bolbitius titubens* (Bull.)Fr., *Clitocybe nuda* (Bull.) H.E. Bigelow & A.H. Sm., *C. tarda* Peck, *Stropharia semiglobata* (Batsch) Quél, *Volvariella speciosa* (Fr.) Singer, *Conocybe* sp., *Coprinus* sp., *Panaeolus* sp., *Psilocybe* sp., etc.

Herbivorous dung has been reported to contain the macerated and undigested remains of plant food and vast quantities of bacteria and animal waste products, such as broken-down red blood cells and bile pigments, etc. (Lodha, 1974; Webster, 1970). It is reported to be rich in water-soluble vitamins, growth factors, and mineral ions, some of which are metabolic by-products of the microbes in herbivore's gut (Lambourne and Reardon, 1962). It is also reported to contain a large amount of readily available carbohydrates (Richardson, 2001b). The nature of herbivore dung has been reported to largely depend on the efficiency of the digestive tract of the animal, which, in turn, has been reported to depend on the animal's digestive anatomy and its microflora. Ruminants are reported to produce fine-textured dung as compared to horses, with a less efficient digestive system, which have been reported to produce much coarser dung (Bell, 1983; Ing, 1989; Richardson, 1998; 2003). Because of the great variation in the feeding habits, habitats, and digestive systems of herbivores, a variety of mushrooms are

documented to grow indiscriminately on any herbivore dung. Their greatest variety has been reported on cow, buffalo, horse, elephant and rabbit dung, but this is reported to be because the majority of research throughout the world has remained focused on the dung of these animals only.

THE WORLD SCENARIO

The distribution of coprophilous fungi is primarily influenced by the presence of herbivores in an area, type of vegetation, kind of dung, climatic conditions and latitudinal environmental gradients (Webster, 1970; Angel and Wicklow, 1975; Kumar *et al.* 1995; Piontelli *et al.*, 2006). The coprophilous mushrooms are common during the rainy season, especially when the relative humidity in the environment is very high. These mushrooms are quite diverse and cosmopolitan in their distribution as is evident from the information gathered from the published literature over a period of time. There are about 35 agaricoid mushroom genera spread over 10 families on which sufficient literature has been published which have been presented in tabulated form **(Table 1).**

COPROPHILOUS AGARICS FROM AUSTRALIA/ OCEANIA

The Australia and Oceania region is surrounded by the Indian, Southern and Pacific Oceans. It includes the entire Australian mainland, such big islands as New Zealand, Tasmania, New Guinea (only its eastern half), and many thousands of tiny, tropical islands of Melanesia, Micronesia and Polynesia regions, scattered throughout the South Pacific. Among Australia's herbivorous wild animals are the Kangaroo, Koala, Gliders and Wallaby. Domestic animals include Horses, Cattle, Goats, Sheep, and Donkey etc. Very little information could be gathered about the occurrence of fimicolous agarics from this region.

Watling and Taylor (1987) in their documentation on the family *Bolbitiaceae* from New Zealand reported *Pholiotina vexans* (P.D. Orton) Bon from cow dung, *Conocybe pubescens* (Gillet) Kühner from horse dung, alongwith two unnamed *Conocybe* species which were also recorded growing on dung. Peter and Buchanan (1995) reported *Psilocybe* species from New Zealand. *Psilocybe argentina* (Spegazzini) Singer was found growing on sheep dung, *P. coprophila* (Bull.: Fr.) P. Kumm. on sheep and horse dung and *P. subcoprophila* (Britzelm.) Sacc. on horse dung. Hausknecht and Krisai-Greilhuber (2003) reported *Panaeolus antillarum* (Fr.) Dennis growing on horse manure heaps from Australia.

COPROPHILOUS AGARICS FROM EUROPEAN REGION

Significant amount of literature is available on coprophilous fungi in general and agarics in particular from the European region. Singer (1977) recorded 06 species of *Agrocybe* Fayod, namely *A. coprophila* Katajev, *A. cubensis* (Murrill) Singer, *A. fimicola* (Speg.) Singer, *A. neocoprophila Singer, A. platysperma* (Peck) Singer, *A. sacchari* (Murrill) Dennis; *10 species of Bolbitius Fr., namely B. coprophilous* (Peck) Hongo, *B. demangei* (Quél.) Sacc. & D. Sacc., *B. exiguous* Singer, *B. glatfelteri* Peck, *B. gloiocyaneus* G.F. Atk., *B. lacteus* J.E. Lange, *B. mesosporus* Singer, *B. umanetucnsis* Singer, *B. variicolor* G.F. Atk., *B. vitellinus* (Pers.) Fr.; 02 species of *Conocybe* Fayod *viz., C. albipes* (G.H. Otth) Hauskn., *C. brunneidisca* (Murrill) Hauskn. and *Pluteolus glutinosus* Clem. growing on dung from this region.

Orton and Watling (1979) recorded *Parasola schroeteri* growing on cattle and horse dung from Europe. Watling (1982) in his work "British Fungus Flora- Agarics and Boleti" reported 13 species falling in 03 agaric genera growing on dung from Scotland and British Isles. These include *Agrocybe subpediades* (Murrill) Watling, *Bolbitius titubans* (Bull.) Fr., *B. variicolor* G.F. Atk., *B. vitellinus* (Pers.) Fr., *Conocybe antipus* (Lasch) Fayod, *C. coprophila* (Kühner) Kühner, *C. farinacea* Watling, *C. fuscimarginata* (Murrill) Singer, *C. intrusa* (Peck) Singer, *C. lenticulospora* Watling, *C. murinacea* Watling, *C. pubescens* (Gillet) Kühner, and *C. rickenii* (Jul. Schäff.) Kühner. These species have been documented from variety of dung types including those of cattle, rabbit, horses, etc.Moser (1984) reported *Panaeolus alcidis* Moser growing on moose dung and on roe deer and reindeer droppings from Sweden.Watling and Gregory (1987) while investigating the British fungi described 16 species of coprophilous mushrooms including 08 species of *Psilocybe,* 07 species of *Panaeolus* and 01 species of *Stropharia.*

The contributions of Uljé and Bas (1988, 1991) and Uljé and Noordeloos (1993, 1997, 1999) to the taxonomy of coprophilous macrofungi from Europe especially Netherlands belonging to coprinoid genera are outstanding. Uljé and Bas (1988) reported 03 species, namely *Parasola megasperma* (P.D. Orton) Redhead, Vilgalys & Hopple, *P. misera* (P. Karst.) Redhead, Vilgalys & Hopple and *P. schroeteri* (P. Karst.) Redhead, Vilgalys & Hopple from pure dung. Uljé and Bas (1991) described 10 species, namely *Coprinus stellatus* Buller, *Coprinellus bisporus* (J.E. Lange) Vilgalys, Hopple & Jacq. Johnson, *C. congregatus* (Bull.) P. Karst., *C. curtus* (Kalchbr.) Vilgalys, Hopple & Jacq. Johnson, *C. ephemerus* (Bull.) Redhead, Vilgalys & Moncalvo, *C. heptemerus* (M. Lange and A.H.Sm.) Vilgalys, Hopple & Jacq. Johnson, *C. heterosetulosus* (Locq. ex Watling) Vilgalys, Hopple & Jacq. Johnson, *C. marculentus* (Britzelm.) Redhead, Vilgalys & Moncalvo, *C. pellucidus* (P. Karst.) Redhead, Vilgalys & Moncalvo and *C. sassii* (M.Lange & A.H.Sm.) Redhead, Vilgalys & Moncalvo from various dung types of different herbivorous animals. Uljé and Noordeloos (1993) documented 06 species, namely *Coprinopsis cordispora* (T. Gibbs) Gminder, *C. nivea* (Pers.) Redhead, Vilgalys & Moncalvo, *C. poliomalla* (Romagn.) Doveri, Granito & Lunghini, *C. pseudocortinatus* (Locq. ex Cacialli, Caroti & Doveri) Doveri, *C. pseudonivea* (Bender & Uljé) Redhead, Vilgalys & Moncalvo, and *C. utrifera* (Joss. ex Watling) Redhead, Vilgalys & Moncalvo, from dung habitats. Uljé and Noordeloos (1997) reported 05 species belonging to coprinoid macrofungi, namely *Coprinopsis filamentifera* (Kühner) Redhead, Vilgalys & Moncalvo, *C. luteocephala* (Watling) Redhead, Vilgalys & Moncalvo, *C. sclerotiorum* (Horvers & de Cock) Redhead, Vilgalys & Moncalvo, *C. vermiculifera* (Joss. ex Dennis) Redhead,

Vilgalys & Moncalvo, and *C. xenobia* (P.D. Orton) Redhead, Vilgalys & and Moncalvo, from dung of herbivore animals. Uljé and Noordeloos (1999) reported 08 species, namely *Coprinopsis bicornis* (Uljé & Horvers) Redhead, Vilgalys & Moncalvo, *C. cinerea* (Schaeff.) Redhead, Vilgalys & Moncalvo, *C. krieglsteineri* (Bender) Redhead, Vilgalys & Moncalvo, *C. lagopus* (Fries) Redhead, Vilgalys, & Moncalvo, *C. macrocephala* (Berk.) Redhead, Vilgalys & Moncalvo, *C. pseudoradiata* (Kühner & Joss. ex Watling) Redhead, Vilgalys & Moncalvo, *C. radiata* (Bolton) Redhead, Vilgalys & Moncalvo and *C. scobicola* (P.D. Orton) Redhead, Vilgalys & Moncalvo from dung localities.

Samorini (1993) reported *Panaeolus cyanescens* (Berk. and Broome) Sacc. as common mushroom growing in the manure of buffalo, cow, and horse in Italy. Jordon (1995) in "The Encyclopedia of Fungi of Britain and Europe" reported 25 species belonging to 07 genera as coprophilous in habit. These include 11 species of *Coprinus*, 04 of *Panaeolus,* 04 of *Psilocybe,* 03 of *Bolbitius,* and 01 species each of *Conocybe, Stropharia* and *Lepiota*. Stamets (1996) documented *Panaeolus subbalteatus* (Berk. & Br.) Sacc. growing caespitosely or gregariously on dung or in well manured ground in autumn, spring and summer seasons and *P. acuminatus* (Schaeff.) Quél. growing scattered to gregariously in well-manured grounds or on dung from Europe.

Richardson and Watling (1997) presented four keys to the coprophilous fungi. Out of these, Keys 1 and 2 are for the coprophilous ascomycetes, Key 4 for the determination of the members of coprophilous *Zygomycota* while Key 3 for the determination of dung-inhabiting basidiomycetes. In Key 3 a total number of 66 species, including 29 species of *Coprinus,* 12 species of *Conocybe,* 08 species of *Psilocybe,* 06 species of *Panaeolus*, 03 species of *Psathyrella,* 02 of *Stropharia*, and 01 species each of *Agrocybe, Bolbitius, Clitocybe*, *Lepista*, *Leucocoprinus,* and *Volvariella* has been keyed out.Kytövuory (1999) originally described *Protostropharia alcis* (Kytöv) Redhead, Thorn & Malloch from Boreal Region of Europe, where it grows on elk dung.

Doveri (2004) published the first monograph on coprophilous fungi from Italy entitled "Fungi Fimicoli Italici". It is regarded as the starting point of a survey on fungi obligatorily or facultatively growing on any kind of dung. It included keys and descriptions covering 80 taxa of *Basidiomycota* and 214 of *Ascomycota* growing both in the natural state and in damp chamber cultures of dung of different herbivorous animals from Italy. Doveri (2010) listed 80 species of coprophilous *Agaricales* detected in the field from Italy and categorized these depending upon their dung source. These included 14 species of *Coprinopsis,* 13 species of *Conocybe,* 11 species each of *Coprinellus* and *Panaeolus,* 06 species of *Psilocybe,* 05 species each of *Agrocybe* and *Coprinus*, 04 species of *Bolbitius,* 03 species each of *Psathyrella* and *Stropharia,* 02 species of *Parasola,* and 01 species each of *Lepista, Leucocoprinus,* and *Volvariella*. Out of the total taxa documented, 54% were reported to be associated with bovine dung, 42% with equine dung, and the remaining 4% with dung of other herbivores. Out of the various agaricoid mushrooms documented about 47% represented species of *Coprinus s.l.* Doveri *et al.* (2010) re-examined the genus *Coprinellus* from its establishment, through demotion as a synonym of *Coprinus,* and up through its current reinstatement. They isolated an agaric from chamois dung and, based on morphological data, regarded it as a new species *Coprinellus mitrinodulisporus*. Doveri (2011) in "Addition to Fungi Fimicoli Italici" updated the work on coprophilous fungi reporting 43 additional species (5 *Basidiomycota* and 38 *Ascomycota*) new to Italy with the introduction of new keys, descriptions of species, and an account on their ecology.

Richardson (2004) reported a total of 81 species of coprophilous ascomycetous and basidiomycetous fungi from 32 herbivore dung samples collected from Iceland. The agaricoid members namely *Coprinopsis cordispora* (T. Gibbs) Gminder, *C. macrocephala* (Berk.) Redhead, Vilgalys and Moncalvo, *C. nivea* (Pers.) Redhead, Vilgalys & Moncalvo, *C. pseudoradiata* (Kühner & Joss. ex Watling) Redhead, Vilgalys & Moncalvo, *C. stercorea* (Fries) Redhead, Vilgalys & Moncalvo, *Coprinellus heptemerus* (M. Lange & A.H. Sm.) Vilgalys, Hopple & Jacq. Johnson, *C. pellucidus* (P. Karst.) Redhead, Vilgalys & Moncalvo, *Parasola misera* (P. Karst.) Redhead, Vilgalys & Hopple, *Panaeolus antillarum* (Fr.) Dennis, *P. semiovatus* (Sowerby) S. Lundell & Nannf., and *Psilocybe subcoprophila* (Britzelm.) Sacc. were reported to be very common on dung. Richardson (2011) in 'Additions to the Coprophilous Mycota of Iceland' article recorded 11 mushrooms from animal dung, namely *Coprinellus heptemerus* (M. Lange & A.H. Sm.) Vilgalys, Hopple & and Jacq. Johnson, *C. pellucidus* (P. Karst.) Redhead, Vilgalys & Moncalvo, *Coprinopsis cordisporus* (T. Gibbs) Watling & M.J. Richardson, *C. ephemeroides* (DC.: Fr.) Watling & M.J. Richardson *C. nivea* (Pers.: Fr.) Redhead, Vilgalys & Moncalvo, *C. radiata* (Bolton: Fr.) Redhead, Vilgalys & Moncalvo, *C. stercorea* (Fr.) Redhead, Vilgalys & Moncalvo, *Panaeolus papilionaceus* (Bull.: Fr.) Quél., *P. semiovatus* (Sowerby: Fr.) var. *phalaenarum* (Fr.) Ew. Gerhardt, *Parasola misera* (P. Karst.) Redhead, Vilgalys & Hopple and *Psilocybe coprophila* (Bull.: Fr.) P. Kumm.

Hausknecht *et al.* (2005) described in all 56 taxa of the genus *Conocybe* from Finland, out of which 08 species, namely *C. farinacea* Watling, *C. fimetaria* Watling, *C. fuscimarginata* (Murrill) Singer, *C. lenticulospora* Watling, *C. pubescens* (Gillet) Kühner, *C. rickenii* (Jul. Schäff.) Kühner, *C. singeriana* Hauskn. and *C. watlingii* Hauskn. have been recorded growing on herbivorous dung or manure. Hausknecht and Contu (2007) reported *Conocybe brunneidisca* (Murrill) Hauskn. from dung localities or in fertilized meadows from Italy. Hausknecht *et al.* (2010) reported *Bolbitius excoriates* Dähncke, Hauskn., Krisai, Contu & Vizzi as a new species growing gregariously on horse dung from Spain.

Larssona and Örstadiusb (2008) while working on dung inhabiting mushrooms in the Nordic countries identified 14 *Psathyrella* species. They documented *Psathyrella fimiseda* Örstadius & E. Larss. and *P. merdicola* Örstadius & E. Larss.

from cow dung, *P. romagnesi* Kits van Wav. from mixtures of straw and dung of horse, more seldom of cow, *P. scatophila* Örstadius & E. Larss. from the dung of badger, horse, cow, and elk, *P. hirta* Peck, *P. purpureobadia* Arnolds, *P. sphaerocystis* P.D. Orton, *P. stercoraria* Kühner & Joss., *P. saponacea* F.H. Møller from horse and cow dung, *P. tenuicula* (P. Karst.) Örstadius & Huhtinen from the dung of wild boar, deer and their allies, *P. conopilus* (Fr.) A. Pearson & Dennis and *P. microrhiza* (Lasch) Konrad & Maubl. from unspecified dung, *P. potteri* A.H. Sm. from mixtures of dung and straw, sometimes on raw dung, and *P. prona* (Fr.) Gillet from manured soil.

Prydiuk (2010) reported fimicolous representatives of the coprinoid taxa as a result of both the use of moist-chambers and the field research from the territory of Ukraine. In all 8 species, namely *Coprinellus bisporus* (J.E. Lange) Vilgalys, Hopple & Jacq. Johnson, *C. brevisetulosus* (Arnolds) Redhead, Vilgalys & Moncalvo, *C. curtus* (Kalchbr.) Vilgalys, Hopple & Jacq. Johnson, *C. heterosetulosus* (Locq. ex Watling) Vilgalys, Hopple & Jacq.Johnson, *C. pellucidus* (P. Karst.) Redhead, Vilgalys & Moncalvo, *C. congregatus* (Bull.) P. Karst., *C. ephemerus* (Bull.) Redhead, Vilgalys & Moncalvo and *Parasola miser* (P. Karst.) Redhead, Vilgalys & Hopple were reported to be associated with dung. Prydiuk (2011) recorded 9 representatives of the coprinoid fungi collected during their investigations on coprophilous mushrooms. Out of these five species, *Coprinopsis cordispora* (T. Gibbs) Gminder, *C. foetidella* (P.D. Orton) A.Ruiz & G. Muñoz, *C. pseudonivea* (Bender & Uljé) Redhead, Vilgalys & Moncalvo, *C. pseudoradiata* (Kühner & Joss. ex Watling) Redhead, Vilgalys & Moncalvo and *C. utrifera* (Joss. ex Watling) Redhead, Vilgalys & Moncalvo] were collected in Ukraine for the first time. For *Coprinopsis ephemeroides* (DC.) G. Moreno, *C. nivea* (Pers.) Redhead, Vilgalys & Moncalvo and *C. radiata* (Bolton) Redhead, Vilgalys & Moncalvo new localities were registered. Házi *et al.* (2011) on the basis of morphological characters and species phylogeny inferred from ITS1-5.8S-ITS2 and β - tubulin gene sequences described a new coprophilous species, *Coprinellus radicellus* Házi, L. Nagy, Papp & Vágvölgyi, from Sweden.

Gierczyk *et al.* (2011) documented a list of fifty-five coprinoid fungi found in Poland. They reported *Coprinellus bisporus* (J.E. Lange) Vilgays, Hoppe & Jacq. Johnson; *C. congregatus* (Bull.) P. Karst., *C. curtus* (Kalchbr.) Vilgalys, Hoppe & Jacq. Johnson; *C. flocculosus* (DC.) Vilgays, Hoppe & Jacq. Johnson; *C. heptemerus* (M. Lange & A. H. Sm.) Vilgalys, Hopple & Jacq. Johnson; *C. heterosetulosus* (Watling) Vilgalys, Hopple & Jacq. Johnson; *C. marculentus* (Britzelm.) Redhead, Vilgalys & Moncalvo; *C. pellucidus* (P. Karst.) Redhead, Vilgalys & Moncalvo; *C. plagioporus* (Romagn.) Redhead, Vilgalys & Moncalvo; *Coprinopsis candidata* (Uljé) Noordel., *C. cordispora* (T. Gibbs) Noordel.; *C. cothurnata* (Godey) Redhead, Vilgalys & Moncalvo; *C. foetidella* (P.D. Orton) Noordel., *C. jonesii* (Peck) Redhead, Vilgalys & Moncalvo; *C. narcotica* (Batsch) Redhead, Vilgalys & Moncalvo; *C. nivea* (Pers.) Redhead, Vilgalys & Moncalvo; *C. pseudofriesii* (Pilát and Svrček) Redhead, Vilgalys and Moncalvo; *C. pseudonivea* (Bender & Uljé) Redhead, Vilgalys & Moncalvo; *C. pseudoradiata* (Watling) Redhead, Vilgalys & Moncalvo; *C. radiata* (Bolton) Redhead, Vilgalys & Moncalvo; *C. trispora* (Kemp & Watling) Redhead, Vilgalys & Moncalvo; *C. tuberosa* (Quél.) Doveri, Granito & Lunghini; *C. xenobia* (P.D. Orton) Redhead, Vilgalys & Moncalvo; *Coprinus sterquilinus* (Fr.) Fr.; *Parasola megasperma* (P.D. Orton) Redhead, Vilgalys & Hopple; *P. misera* (P. Karst.) Redhead, Vilgalys & Hopple and *P. schroeteri* (P. Karst.) Redhead, Vilgalys & Hopple as coprophilous species growing on herbivorous dung and dung mixed with straw. Gierczyk *et al.* (2014) described 19 coprinoid fungi, found in Poland, out of which *Coprinellus radicellus* Házi, Nagy, Vágvölgyi & Papp was recorded growing on moose dung; *Coprinopsis annulopora* (Enderle) P. Specht & H. Schubert on horse manure; *C. candidolanata* (Doveri & Uljé) Keirle, Hemmes & Desjardin on deer and sheep dung and *C. scobicola* (P.D. Orton) Redhead, Vilgalys & Moncalvo on dung compost.

Ruiz and Ruiz (2016) reported *Coprinopsis foetidella* (P. D. Orton) A. Ruiz & G. Muñoz growing on alpaka dung from Navarre in Spain. Melzer (2017) provided an exhaustive dichotomous key including most of the previously described coprinoid species from Europe, some of which have since been transferred from the genus *Psathyrella*. This key is based predominantly on microscopic characteristics and drawings. Some macroscopic and ecological features are also included for presenting an overview of more than 200 coprinoid mushrooms growing on soil, litter, wood, herbicol, open habitat, indoor, burned ground, calcareous ground along with those growing on dung and fertilized substratum.

COPROPHILOUS AGARICS FROM ANTARCTICA

Antarctica is a remote and inhospitable continent. The climate is the coldest and driest known on Earth; nevertheless it is not uniform across the continent, and different climatic regions can be distinguished (Øvstedal and Smith, 2001). The prevailing Antarctic conditions of low temperature, low water availability, frequent freezethaw cycles, low annual precipitation, strong winds, high sublimation and evaporation, high incidence of solar and especially ultraviolet radiation together constitute significant limiting factors for plant and animal life. Therefore, the biology of Antarctica, more than other continents, is dominated by microorganisms (Friedmann, 1993; Ruisi *et al.*, 2007), with a high level of adaptation and able to withstand extreme conditions.

There are about 20 species of macro-fungi (mushrooms) that have been reported to exist in the Antarctic, according to the British Antarctic Survey (BAS), which has several research stations around the peninsula region. The mushrooms belonging to the genus *Galerina* which can live on many different substrates such as wood, moss or other types of organic materials were discovered on an island off the Antarctic Peninsula (Rejcek, 2012). This proved the existence of mushrooms in continental Antarctica, although the fruiting bodies on dung have never been recorded.

COPROPHILOUS AGARICS FROM SOUTH AMERICAN REGION

Much of the work on coprophilous mushrooms in the South American region is largely from Brazil, Falkland, Venezuela, Columbia, etc. Guzmán (1978a) described *Panaeolus venezolanus* Guzmán from Venezuela. It was documented growing gregariously on cow dung or on rich soils, in meadows of the subtropical forests. Arora *(1986)* documented *P. cubensis* (Earle) Singer from the dung localities of Columboa. Stamets (1996) documented *Panaeolus subbalteatus* (Berk. & Br.) Sacc. growing caespitosely or gregariously on dung or in well manured ground in autumn, spring and summer seasons from South America.

Richardson (2001a) documented eight species of coprophilous mushrooms from the state of Matto Grosso do Sul, Brazil. These are *Cyathus stercoreus* (Schwein.) De Toni, *Coprinopsis stercorea* (Fr.) Redhead, Vilgalys & Moncalvo, *C. cordispora* (T. Gibbs) Gminder, *C. radiata* (Bolton) Redhead, Vilgalys & Moncalvo, *Coprinellus curtus* (Kalchbr.) *Vilgalys*, *Hopple & Jacq*. *Johnson,* C. *heptemerus* (M. Lange & A.H. Sm.) Vilgalys, Hopple & Jacq. Johnson, *C. pellucidus* (P. Karst.) Redhead, Vilgalys & Moncalvo, along with an unidentified species similar to *Coprinopsis stercorea* (Fries) Redhead, Vilgalys & Moncalvo. Cortez and Coelho (2004) reported *Stropharia semiglobata* (Batsch) Quél. growing solitary on horse dung from Brazil. Wartchow *et al.* (2007) published three *Psilocybe* (Fr.) P. Kumm. growing on dung in Pernambuco State, Northeastern Brazil. Wartchow *et al.* (2010) reported *Panaeolus cyanescens* (Berk. & Broome) Sacc. growing on cow dung in man-made pastures from Pernambuco State, Northeast Brazil. Cortez and Silveira (2008) while conducting the survey of the genus *Stropharia* in the Brazilian State of Rio Grande do Sul recorded three dung-inhabiting species of the genus. They revealed the occurrence of *Protostropharia alcis* subsp. *austrobrasiliensis* (Cortez & R.M. Silveira) C. Hahn growing gregariously on cow dung substrate. *Protostropharia dorsipora* (Esteve-Rav. & Barassa) Redhead and *P. semiglobata* (Batsch) Redhead, Moncalvo & Vilgalys, both were recorded growing solitary on cow dung in pastures.

Watling and Richardson (2010) recorded 28 taxa of coprophilous mushrooms from the Falkland Islands. These belong to 11 genera namely *Agrocybe, Bolbitius, Conocybe, Clitocybe, Clitopilus, Coprinellus, Coprinopsis, Parasola, Panaeolus, Psilocybe,* and *Stropharia* of 05 families namely *Bolbitiaceae*, *Entolomataceae*, *Psathyrellaceae*, *Strophariaceae*, and *Tricholomataceae* of *Basidiomycota*. Out of the species recorded, *Clitocybe amarescens* Harmaja was collected from cattle and sheep dung-enriched soil; *Coprinellus brevisetulosus* (Arnolds) Redhead, Vilgalys and Moncalvo, *Coprinellus curtus* (Kalchbr.) Vilgalys, Hopple & Jacq. Johnson, *C. heptemerus* (M. Lange & A.H. Sm.) Vilgalys, Hopple & Jacq. Johnson, *Coprinopsis ephemeroides* (DC.) G. Moreno, *C. pachysperma* (P.D. Orton) Redhead, Vilgalys & Moncalvo, *Psilocybe coprophila* (Bull.) P. Kumm., *P. cubensis* (Earle) Singer, *P. moelleri* Guzmán and *Panaeolus papilionaceus* (Bull.) Quél. from horse dung; *Coprinellus pellucidus* (P. Karst.) Redhead, Vilgalys & Moncalvo, *Coprinopsis vermiculifera* (Joss, ex Dennis) Redhead, Vilgalys & Moncalvo, *Conocybe digitalina* (Velen.) Singer, and *C. magnispora* (Murrill) Singer exclusively from cattle dung; *Coprinopsis cordispora* (T. Gibbs) Gminder, *Coprinopsis nivea* (Pers.) Redhead, Vilgalys & Moncalvo, *Psilocybe subcoprophila* (Britzelm.) Sacc., *Agrocybe fimicola* (Speg.) Singer, *Bolbitius vitellinus* (Pers.) Fr., *Panaeolus antillarum* (Fr.) Dennis, *P. subfirmus* P. Karst. and *P. semiovatus* (Sowerby) S. Lundell & Nannf. from cattle and horse dung; and *Coprinopsis radiata* (Bolton) Redhead, Vilgalys & Moncalvo and *Coprinopsis stercorea* (Fr.) Redhead, Vilgalys & Moncalvo from horse, sheep and rabbit dung; *Parasola misera* (P. Karst.) Redhead, Vilgalys & Hopple has been reported from horse, cattle, sheep and rabbit dung; *Conocybe pubescens* (Gillet) Kühner from horse and cow dung; *Clitopilus passeckerianus* (Pilát) Singer from sheep dung, and *Prototropharia semiglobata* (Batsch) Redhead, Moncalvo & Vilgalys from horse, cattle, sheep dung, and hare dung pellets, respectively.

Calaça *et al.* (2014) published a checklist of coprophilous fungi and other fungi recorded on dung from Brazil. They confirmed 18 taxa belonging to order *Agaricales* growing on herbivorous dung which are *Cyathus stercoreus* (Schwein.) De Toni; *Coprinellus curtus* (Kalchbr.) Vilgalys, Hopple & Jacq. Johnson; *C. heptemerus* (M. Lange & A.H. Sm.) Vilgalys, Hopple & Jacq. Johnson; *C. pellucidus* (P. Karst.) Redhead, Vilgalys & Moncalvo; *Coprinopsis cordispora* (T. Gibbs) Gminder; *C. nivea* (Pers.) Redhead, Vilgalys & Moncalvo; *C. radita* (Bolton) Redhead, Vilgalys & Moncalvo; *C. stercorea* (Fr.) Redhead, Vilgalys and Moncalvo; *Parasola misera* (P. Karst.) Redhead, Vilgalys & Hopple; *Psilocybe argentina* (Speg.) Singer; *P. caeruleoannulata* Singer ex Guzmán; *P. coprophila* (Bull.) P. Kumm.; *P. cubensis* (Earle) Singer; *P. merdaria* (Fr.) Ricken; *P. pegleriana* Guzmán; *P. subcubensis* Guzmán; *Protostropharia alcis* (Kytöv.) Redhead, Thorn & Malloch and *P. semiglobata* (Batsch) Redhead, Moncalvo & Vilgalys. Melo *et al.* (2016) reported twelve species of dung inhabiting mushrooms during a survey of coprophilous fungi in Pernambuco, northeastern Brazil. These mushrooms are *Bolbitius demangei* (Quél.) Sacc. & D. Sacc.; *Conocybe siliginea* (Fr.) Kühner; *Coprinellus angulatus* (Peck) Redhead, Vilgalys & Moncalv; *C. marculentus* (Britzelm.) Redhead, Vilgalys & Moncalvo, *Coprinopsis cinerea* (Schaeff.) Redhead, Vilgalys & Moncalvo; *C. cothurnata* (Godey) Redhead, Vilgalys & Moncalvo; *C. pseudoradiata* (Kühner & Joss. ex Watling) Redhead, Vilgalys & Moncalvo; *C. stercorea* (Fr.) Redhead, Vilgalys & Moncalvo; *C. vermiculifer* (Joss. ex Dennis) Redhead, Vilgalys & Moncalvo; *Coprinopsis foetidella* (P.D. Orton) A.Ruiz, G. Muñoz; *C. patouillardii* (Quél.) G. Moreno and *Panaeolus antillarum* (Fr.) Dennis. Seger *et al.* (2017) reported *Protostropharia alcis* ssp. *austrobrasiliensis* (Cortez & R.M. Silveira) C. Hahn and *P. dorsipora* (Esteve-Rav. & Barassa) Redhead as growing on manure of cattle and horse, inside forest and in pastures from South Brazil.

COPROPHILOUS AGARICS FROM NORTH AMERICAN REGION AND CANADA

There are reports of agarics growing on different types of dung some parts of North America and Canada. Lange and Smith (1953) while working on the coprinoid ephemerus group reported 09 coprophilous species, namely *Coprinellus bisporus* (J.E. Lange) Vilgalys, Hopple & Jacq., *C. congregatus* (Bull.) P. Karst., *C.* ephemerus (Bull.) Redhead, Vilgalys & Moncalvo, *C. heptemerus* (M. Lange & A.H. Sm.) Vilgalys, Hopple & Jacq. Johnson, *C. heterosetulosus* (Locq. ex Watling) Vilgalys, Hopple & Jacq. Johnson, *C. marculentus* (Britzelm.) Redhead, Vilgalys & Moncalvo, *C. pellucidus* (P. Karst.) Redhead, Vilgalys & Moncalvo, *C. sassii* (M. Lange & A.H. Sm.) Redhead, Vilgalys & and Moncalvo and *Coprinus stellatus* Buller from North America.

Miller (1968) reported *Panaeolus solidipes* (Peck) Sacc. growing solitary on horse dung during summer season from Alaska in US and Yukon in Canada. Ghouled (1972) reported *Psilocybe cubensis* (Earle) Singer and *Panaeolus cinctulus* (Bolton) Saccardo usually located on cow manure in North America. Van de Bogart (1976) reported 04 species viz., *Coprinus comatus* var. comatus (Müll.) Gray, *C. roseistipitatus* Bogart, *C. spadiceisporus* Bogart and *C. umbrinus* Cookie & Massee, belonging to coprophilous habitats from Washington, United States. Van de Bogart (1979) documented 03 species inhabiting dung of herbivores. Out of these, *Coprinopsis radiata* (Bolton) Redhead, Vilgalys & Moncalvo was collected from dung of all kinds of herbivores, *C. cinerea* (Schaeff.) Redhead, Vilgalys & Moncalvo on horse dung, and Coprinus undulatus Bogart on compost heaps.

Stamets (1978) indicated the association of *Psilocybe cubensis* (Earle) Singer with elephant dung in the southeastern United States. Badham (1984) reported that *Psilocybe cubensis* (Earle) Singer grows commonly in the dung of cattle and horses in North America which is probably the most commonly eaten hallucinogenic mushroom in this area. One of the most common descriptions of the psychological effects of this mushroom given is that of a "dream-like" state. Moser (1984) reported *Panaeolus alcidis* Moser growing on moose dung from Saskatchewan and Canada.

According to Ammirati *et al.* (1985), *Psilocybe semilanceata* (Fr.) P. Kumm. is widespread in North America, eastern Canada and the Pacific Coast and grows scattered to gregarious in lawns, meadows, pastures and on or near dung. Arora (1986) reported *Panaeolus solidipes* (Peck) Sacc. growing scattered to gregarious on horse dung and on manure in the month of January from California and in September from Arizona and *Panaeolus cyanescens* (Berk. & Br.) Sacc. growing solitary to scattered or in groups on or near dung in the paustures of Hawaii islands. Stamets (1996) recorded *P. cyanescens* (Berk. & Br.) Sacc. growing scattered to gregariously on dung in pastures and fields from Hawaii, Louisiana and Florida in the United States, *P. subbalteatus* (Berk. & Br.) Sacc. growing caespitosely or gregariously on dung or in well manured ground in autumn, spring and summer seasons and *P. acuminatus* (Schaeff.) Quél. growing scattered to gregariously in well-manured grounds or on dung from North America. He reported *Psilocybe semilanceata* (Fr.) P. Kumm. growing scattered to gregarious in pastures, fields, lawns or rich grasslands grazed by sheep and cows from California and British Columbia.

Arora (1986) in "Mushrooms Demystified" documented 21 species growing on dung, manure, or compost piles from different parts of North America including California, Colorado, Washington, Mexixo, etc., The documented species include *Chlorophyllum rhacodes* (Vittad.) Vellinga, *Coprinus ephemeroides* (Bull.) Fr., *C. spadiceisporus* Bogart, *C. sterquilinus* (Fr.) Fr., *C. umbrinus* Cooke & Massee, *Coprinopsis radiata* (Bolton) Redhead, Vilgalys & Moncalvo, *C. nivea* (Pers.) Redhead, Vilgalys & Moncalvo, *Coprinellus domesticus* (Bolton) Vilgalys, Hopple & Jacq. Johnson, *C. ephemerus* (Bull.) Redhead, Vilgalys & Moncalvo, *Parasola miser*a (P. Karst.) Redhead, Vilgalys & Hopple, *Panaeolus campanulatus* (Bull.) Quél., *P. cyanescens* (Berk. & Br.) Sacc., *P. semiovatus* (Sowerby) S. Lundell & Nannf., *P. solidipes* (Peck) Sacc., *P. subbalteatus* (Berk. & Br.) Sacc., *Psilocybe coprophila* (Bull.) P. Kumm., *P. cubensis* (Earle) Singer, *Stropharia semiglobata* (Batsch) Quél., *Agrocybe pediades* (Pers.: Fr.) Fayod, *Conocybe tenera* (Schaeff.) Fayod and *Bolbitius titubans* (Bull.) Fr. Arora (1986) documented *P. cyanescens* from the dung ilocalities of Hawaiian Islands.

Keirle *et al.* (2004) documented twentynine species belonging to *Coprinus, Podaxis, Coprinopsis*, *Coprinellus*, and *Parasola* from the Hawaiian Islands. As many as 10 collections belonging to *Coprinus, Coprinopsis* and *Coprinellus* were reported to be dung inhabiting. Out of these, *Coprinus sterquilinus* (Fr.) Fr., *Coprinopsis radiate* (Bolton) Redhead, Vilgalys & Moncalvo, *Coprinopsis sclerotiorum* (Horvers & de Cock) Redhead, Vilgalys & Moncalvo and *Coprinopsis villosa* L. Nagy, Desjardin, Vágvölgyi & Papp were reported from horse dung, *Coprinopsis cordispora* (T. Gibbs) Gminder, *Coprinopsis stercorea* (Fries) Redhead, Vilgalys & Moncalvo, and *Coprinellus pellucidus* (P. Karst.) Redhead, Vilgalys & Moncalvo from horse and cow dung and rarely on goat dung. *Coprinopsis candidolanata* (Doveri & Uljé) Keirle, Hemmes & Desjardin was recorded growing on goat dung, *C. cothurnata* (Godey) Redhead, Vilgalys & Moncalvo on cow dung and *Coprinellus curtus* (Kalchbr.) *Vilgalys*, *Hopple* & *Jacq*. *Johnson* from deer dung.

COPROPHILOUS AGARICS FROM AFRICAN REGION

Not much work is available specifically on the coprophilous agarics of this region. Pegler (1977) in his monumental work on agaric flora of East Africa reported 13 mushrooms including 03 species of *Psilocybe* (Fr.) P.Kumm., 03 species of *Coprinus* Pers., 03 species of *Panaeolus* (Fries) Quél., 01 species each of *Agrocybe* Fayod, *Bolbitius* Fr., *Conocybe* Fayod, and *Stropharia* (Fries) Quél. growing in coprophilous habitats. Stamets (1996) reported dung inhabiting *Panaeolus tropicalis* Oláh from Central Africa, *P. africanus* Oláh growing on hippopotamus and elephant dung from Central and South Africa and *P. subbalteatus* (Berk. & Br.) Sacc. growing caespitosely or gregariously on dung or in well

manured ground in autumn, spring and summer seasons from many parts of the continent.

According to Reid and Eicker (1999), the species *Panaeolus antillarum* (Fr.) Dennis is able to grow on dung from a wide range of herbivorous mammals including cattle, horses, buffaloes, elephants and rhinoceros. They recorded it growing on pile of stable manure, on elephant dung, and on cattle dung in open pasture during the months of March and April from South Africa.

COPROPHILOUS MUSHROOMS FROM ASIAN REGION

In the Asian subcontinent much of the work on coprophilous mushrooms has been done in India, which has been dealt separately. However, there are scattered reports of some work on these fungi from Sri Lanka, China, Thailand Nepal, Iraq, Turkey, Combodia, etc. Pegler (1986) while working on agaric flora of Sri Lanka recorded *Bolbitius fissus* Berk. and Broome, *Coprinellus fimbriatus* (Berk. & Broome) Redhead, Vilgalys & Moncalvo*, Coprinopsis macrocephala* (Berk.) Redhead, Vilgalys & Moncalvo and *Psilocybe pseudobullacea* (Petch) Pegler from unspecified dung, *Panaeolus rubricaulis* Petch & *P. cyanescens* (Berk. & Broome) Sacc. from manured soil, and *Psilocybe rostrata* from elephant dung.

McKenna (1988) recorded *Psilocybe cubensis* often occuring in association with the manure of *Bos indicus* in Thailand. McKenna (1992) in his book 'The Archaic Revival' has created a web of understanding that he has gleaned from both his psychedelic experiences and research. The work stretches from the prehistoric veldt of Africa to the unimaginable world beyond the transcendental object at the end of history. He describes in this book that at an archeological site in the Non Nak Tha region of northern Thailand, the bones of zebu cattle were unearthed in conjunction with human remains. We know that *Psilocybe cubensis* flourishes in the manure of cattle and buffaloes in this region of northeastern Thailand. Terence McKenna has suggested that the temporal and physical relationship between the human bones and the bones of cattle gives conclusive evidence that psychoactive mushrooms were known to the people who frequented this region about 15,000 years ago.

Zhishu *et al.* (1993) have reported *Panaeolus antillarum* (Fr.) Dennis growing gregariously on cow dung and *P. cyanescens* (Berk. & Br.) Sacc. growing scattered to gregariously on dunghills or grass from China's Guangdong Province. Stamets (1996) reported dung inhabiting *Panaeolus tropicalis* Oláh from Cambodia. Guzmán and Kasuya (2004) noted *Psilocybe pseudobullacea* (Petch) Pegler and *P. subcubensis* Guzmán growing on rhinoceros manure from Nepal.

Pollock (1976) reported *Panaeolus tropicalis* Ola'h as "fruiting in the dung of cattle and wild animals" from Cambodia (Kampuchea) in Southeast Asia. Türkoğlu *et al.* (2007) reported *Coprinopsis macrocephala* (Berk.) Redhead, Vilgalys & Moncalvo growing on horse manure, in the month of May from Kayseri, Turkey. Ediriweera *et al.* (2015) described *Panaeolus sphinctrinus* (Fr) Quél. and *P. foenisecii* (Pers.) J. Schröt. on elephant dung for the first time from dry zone forest reserves of Sri Lanka. Wang and Tzean (2015) identified dung-associated four taxa, *Panaeolus antillarum* (Fr.) Dennis, *Conocybe nitrophila* (Hauskn.) Wang & Tzean*, Psilocybe angulospora* Wang & Tzean and *Protostropharia ovalispora* Wang & Tzean*,* from Qingtiangang, Yangmingshan National Park in Taiwan.

Al-Khesraji (2018) collected macrofungi specimens from Tikrit and Dujail districts of Salahadin Governorate, North Central Iraq between 2017 and 2018. *Panaeolus papilionaceus* (Bull. ex Fries) Quél. was found growing singly or gregariously on cow dung; fruiting spring and winters. Toma *et al.* (2018) found *Panaeolus papilionaceus* growing on dung of horses and cows in Erbil city of Kurdistan region of Iraq.

THE INDIAN SCENARIO

The striking variation in Indian climate plays a determinate role in growth and development of wide variety of mushrooms including coprophilous mycoflora. During the past four decades much progress has been made in the field of mushroom research in India in general. The review of literature reveals the following articles which have been published on coprophilous mushrooms and about 140 species belonging to about 30 genera are known to be growing wild on dung localities in India.

COPROPHILOUS AGARICS FROM NORTH INDIA

The earliest contribution on coprophilous mushrooms from India was by Rea (1922) who recorded 10 coprophilous species from the state of Punjab. These were *Coprinellus ephemerus* (Bull.) Redhead, Vilgalys & Moncalvo from rabbit dung; *Bolbitius tener* Berk. from donkey dung; *B. vitellinus* (Pers.) Fr. from horse dung; *Coprinus filiformis* Berk. & Broome from the dung of nilgai; *C. gibbsii* Massee & Crossl.*, C. hendersonii* (Berk.) Fr. and *C. stellaris* Quél. from dung of Zebra; *C. nycthemerus* Fr. from cow dung; *C. papillatus* (Batsch) Fr. from sambhar dung; and *Protostropharia semiglobata* (Batsch) Redhead, Moncalvo & Vilgalys from camel dung.

Mahju (1933) reported mushrooms on dung of herbivores collected from various zoological gardens. *Bolbitius vitellinus* (Pers.) Fr. was found growing on horse dung; *Coprinopsis nivea* (Pers.) Redhead, Vilgalys & Moncalvo on unspecified animal dung and *Coprinus papillatus* (Batsch) Fr. on sambhar dung from Punjab. Ginai (1936) contributed to the study of coprophilous mushrooms by isolating 3 genera belonging to basidiomycetes from the dung of donkey, nilgai, zebra, cow and camel. *Bolbitius tener* Berk. was documented from donkey dung; *Coprinus filiformis* Berk. & Broome from dung of nilgai; *C. gibbsii* Massee & Crossl. and *C. hendersonii* (Berk.) Fr. from Zebra dung; *C. nycthemerus* Fr. from the dung of cows and *Protostropharia semiglobata* (Batsch) Redhead, Moncalvo & Vilgalys from the dung of camel from Punjab.

Rawla *et al.* (1982) reported *Agrocybe semiorbicularis* (Bull.) Quél. growing on dung and *Leucocoprinus cretatus* Lanzoni growing on manure heaps and heavily manured beds from

Punjab. Sarwal and Rawla (1983) documented coprophilous species of *Conocybe* growing on horse dung [*Conocybe siliginea* f. *rickenii* (Jul. Schäff.) Arnolds] from Punjab. Purkayastha and Chandra (1985) listed *Agaricus brunnescens* Peck from the manure heaps in Punjab. Kaushal and Grewal (1992) reported *Coprinus comatus* (O.F. Müll.) Pers. growing on horse dung, and *C. papillatus* (Batsch) Fr. growing on panther dung from Punjab.

Saini and Atri (1995) reviewed the exploratory work on mushrooms from Punjab and listed 94 taxa spread over 24 genera from Punjab plains, out of which 16 species are listed to be coprophilous. These include *Agaricus brunnescens* Peck from manure heaps; *Agrocybe pediades* (Fr.) Fayod from mixed dung; *Bolbitius tener* Berk. from donkey dung; *Bolbitius vitellinus* (Pers.) Fr., *Conocybe siliginea* f. *rickenii* (Jul. Schäff.) Arnolds and *Coprinus comatus* (O.F. Müll.) Pers. from horse dung; *C. filiformis* Berk. & Broome from dung of nilgai; *C. gibbsii* Massee & Crossl.; *C. hendersonii* (Berk.) Fr. and *C. stellaris* Quél.from dung of Zebra; *C. nycthemerus* Fr. from dung of cows; *C. papillatus* (Batsch) Fr. growing on sambhar and panther dung; *Coprinopsis nivea* (Pers.) Redhead, Vilgalys & Moncalvo from unspecified animal dung; *Coprinellus ephemerus* (Bull.) Redhead, Vilgalys & Moncalvo from rabbit dung; *Leucocoprinus cretatus* Lanzoni from manure heaps and heavily manured beds and *Protostropharia semiglobata* (Batsch) Redhead, Moncalvo & Vilgalys growing on camel dung.

Atri and Kaur (2004) gave an illustrated account of 10 taxa of coprinoid macrofungi recorded from Patiala. Out of these, 03 taxa were reported from coprophilous habitats. *Coprinellus micaceus* var. *macrosporus* Atri & Kaur was collected growing in clusters on cattle dung manured soil under *Psidium guazava* tree in the month of January while *Coprinopsis patouillardii* (Quél.) G. Moreno was recorded growing on dung under *Albizzia lebbek* tree in September and *Coprinopsis radiata* (Bolton) Redhead, Vilgalys & Moncalvo was documented from cattle dung in the month of September.

Atri *et al.* (2009a) recorded and described 03 species with a coprophilous habitat from Punjab, *viz*. *Bolbitius titubans* (Bull.) Fr. growing solitary on buffalo dung in the month of September, *Conocybe brachypodii* (Velen.) Hauskn. & Svrček growing in groups on cattle dung in June and *C. crispa* (Longyear) Singer growing in caespitose cluster on cattle dung in August. Atri *et al.* (2012) made collections of *Conocybe* Fayod from various dung localities of Punjab. They described four coprophilous species of the genus, namely *Conocybe apala* (Fr.) Arnolds growing solitary or scattered on buffalo dung; *C. subxerophytica* var. *brunnea* Hauskn. growing in groups on horse dung; *C. subxerophytica* var. *subxerophytica* Singer & Hauskn. growing scattered on buffalo dung and *C. uralensis* Hauskn., Knudsen & Mukhin growing in groups on buffalo dung heap. All were recorded for the first time from India.

Amandeep *et al.* (2013a) described two new coprophilous varieties of *Panaeolus* from Punjab, India. *P. africanus* var. *diversistipus* Amandeep Kaur, NS Atri & Munruchi Kaur was found growing solitary on a cattle dung heap and *P. speciosus* var. *pilocystidiosus* Amandeep Kaur, NS Atri & Munruchi Kaur was growing scattered on cattle mixed dung. Amandeep *et al.* (2013b) reported six coprophilous species of the genus *Bolbitius* Fr., namely *B. coprophilus* (Peck) Hongo*, B. demangei* (Quél.) Sacc. & Sacc*., B. glatfelteri* Peck*, B. marginatipes* Zeller*, B. titubans* (Bull.) Fr. and *B. vitellinus* (Pers.) Fr. from a variety of herbivorous dung types. A dichotomous key to aid in the identification of these taxa was given.

Kaur *et al.* (2013a) discovered a large spored variant of *Rhodocybe popinalis (Fr.)* Singer, *R. popinalis* var. *macrosporus* Amandeep Kaur, NS Atri & Munruchi Kaur, growing on a mixed cattle and horse dung heap from Punjab. Kaur *et al.* (2013b) described a new species, *Psathyrella fimicola* NS Atri, Munruchi Kaur & Amandeep Kaur, found growing on horse dung from Patiala district of Punjab state. Kaur *et al.* (2013c) described and illustrated a new mushroom variety, *Protostropharia semiglobata* var. *punjabensis* Amandeep Kaur, NS Atri & Munruchi Kaur, growing on cow dung in Punjab. Hahn (2014) provided an overview of the taxonomy and ecology of the genus *Protostropharia* and a key of the genus including taxa not detected in Europe. He proposed a new combination for *Protostropharia semiglobata* var. *punjabensis* and regarded it as subspecies of *Protostropharia alcis* and named it as *Protostropharia alcis* subsp. *punjabensis* (Amandeep Kaur, NS Atri & Munruchi Kaur) C. Hahn.

Amandeep *et al.* (2014) discussed the diversity of *Coprinopsis* P. Karst. species from the coprophilous habitats from throughout the Punjab state. Twelve taxa, namely *C. cinerea* (Schaeff.) Redhead, Vilgalys & Moncalvo*; C. cothurnata* var. *equsterca* Atri, A. Kaur & M. Kaur*; C. foetidella* (P. D. Orton) A. Ruiz & G. Muñoz*; C. lagopides* var. *lagopides* (P. Karst.) Redhead; Vilgalys & Moncalvo*; C. lagopus* (Fr.) Redhead, Vilgalys & Moncalvo*; C. macrocephala* (Berk.) Redhead, Vilgalys & Moncalvo*; C. nivea* (Pers.) Redhead, Vilgalys & Moncalvo*; C. pseudonivea* (Bender & Uljé) Redhead, Vilgalys & Moncalvo*; C. radiata* (Bolton: Fr.) Redhead, Vilgalys & Moncalvo*; C. radiata* var. *macrocarpa* Atri, A. Kaur & M. Kaur*; C. scobicola* (P.D. Orton) Redhead, Vilgalys & Moncalvo and *C. vermiculifer* (Joss.: Dennis) Redhead, Vilgalys & Moncalvo were reported. Out of these, C. *radiata* var. *macrocarpa* and *C. cothurnata* var. *equsterca* were new mushroom varieties. In this paper, all these taxa were described, illustrated, and compared with similar species. A dichotomous key for their identification was also given.

Kaur *et al.* (2014a) reported two new coprophilous species of *Panaeolus*, namely *P. cyanoannulatus* Atri, M. Kaur & A. Kaur and *P. lepusstercus* Atri, M. Kaur & A. Kaur from Punjab. *Panaeolus cyanoannulatus* was collected on a mixed cow and horse dung heap and *P. lepusstercus* was located growing scattered on rabbit pellets. Kaur *et al.* (2014b) described two new species of *Agaricus, A. stellatus-cuticus* Atri, M. Kaur & A. Kaur and *A. flavistipus* Atri, M. Kaur & A. Kaur, collected on sheep dung and buffalo dung, respectively. Kaur *et al.* (2014c) discussed the *diversity of Panaeolus* growing on herbivorous dung from Punjab. An account of 16 species collected from a variety of coprophilous habitats were

described and discussed. Kaur *et al.* (2014d) gave an account of two *Agrocybe* species, *viz*. *A. microspora* Singer & *A. pediades* (Fr.) Fayod collected from coprophilous habitats of Punjab state. Kaur *et al.* (2014e) documented *Panaeolus sphinctrinus* var. *minor* (Fr.) Singer, *P. tropicalis* Oláh and *Psathyrella castaneifolia* (Murrill) A.H. Sm. growing on dung from Punjab state.Kaur and Kaur (2015) reported *Psilocybe uda* var. *elongata* (Pers.) Gillet and *P. coprophila* (Bull.) P. Kumm. growing scattered on animal dung from Punjab.

Amandeep *et al.* (2015a) recorded the diversity of species of the genus *Conocybe* collected on dung from Punjab. This research paper represented 22 collections belonging to 16 *Conocybe* species growing on five diverse dung types. Amandeep *et al.* (2015b) worked out the taxonomic details of eight coprophilous agarics, namely *Agaricus cupreobrunneus* (Schäffer & Steer: Møller) Pilát, *A. halophilus* Peck, *Coprinus comatus* var. *caprimammillatu* Bogart, *Lepiota epicharis* var. *occidentalis* Dennis, *L. thrombophora* (Berk. & Br.) Sacc., *L. subincarnata* J.E. Lange, *L. xanthophylla* P.D. Orton and *Leucocoprinus straminellus* (Sowerby) Pat., belonging to the family *Agaricaceae* from various dung localities of Punjab state in India. All these taxa were described along with their dung sources, illustrated with line drawings of morphological and anatomical features and compared with similar such taxa from elsewhere. Habitat photographs and a key to their determination have also been provided. Amandeep *et al.* (2015c) gave an account of five *Psathyrella* species from Punjab state along with key for their identification. The collections of the identified taxa were obtained from a variety of coprophilous habitats having different herbivorous dung types. These belong to *Psathyrella kauffmanii* var. *kauffmanii* Smith, *P. vanhermanii* Smith, *P. fimicola* N.S. Atri, Munruchi Kaur & Amandeep Kaur, *P. sphaerocystis* Orton and *P. flocculosa* (Earle) A.H. Smith. For all the taxa, dung types on which they were found growing are also mentioned.

Amandeep *et al.* (2015d) gave an account of the eco-taxonomic studies on the coprophilous mushrooms in Punjab, India. The information is primarily based on the survey to various dung localities of the state undertaken during the years 2007-2011. A total number of 172 collections of coprophilous mushrooms belonging to 95 species spread over 20 genera and 07 families of the order *Agaricales* were examined. In this paper an account of the distribution of these mushrooms in Punjab in different seasons, regions, habitats, and growing habits along with their economic utility, habitat management and conservation has been discussed. Amandeep *et al.* (2015e) published a checklist consisting of 135 coprophilous species belonging in 27 genera and 10 families of the Order *Agaricales* from India. The geographical distribution of the species covering 13 States (Assam, Bihar, Gujarat, Himachal Pradesh, Jammu and Kashmir, Karnataka, Kerala, Maharashtra, Orissa, Punjab, Tamil Nadu, Uttar Pradesh and West Bengal) and 2 Union Territories (Chandigarh, New Delhi) has been discussed in this manuscript. The checklist is an attempt to provide updated information regarding the diversity of coprophilous agarics in India. Kaur *et al.* (2016) documented *Agaricus bernardii* (Quél.) Sacc. growing around the heap of dung manure from Punjab. The species is reported to be edible in literature.

Vishwakarma *et al.* (2017) published a checklist of 153 species of macrofungi belonging to 34 families primarily based on the survey of the north eastern part of Uttar Pradesh state, especially Gorakhpur. They reported *Coprinus comatus* (Müll.: Fr.) Gray; *Coprinopsis cothurnata* (Godey) Redhead, Vilgalys & Moncalvo; *C. foetidella* (P.D. Orton) A.Ruiz & G. Muñoz; *Panaeolus ater* (J.E. Lange) Kühner and Romagn.; *P. papilionaceous* (Bull.) Quél.; and *Calocybe indica* Purkayastha and A. Chandra as coprophilous, growing on animal dung. Singh *et al.* (2018) undertook a study on the taxonomy and diversity of macrofungi w.e.f. March 2014 to July 2016 in different localities of Gorakhpur district of Uttar Pradesh. Out of 14 *Coprinus* species collected and identified, they found habitat of two species coprophilous. *Coprinus comatus* (O.F. Müll.) Pers. was found growing in groups on manure and *C. radiatus* (Bolt.: Fr.) S.F. Gray growing in groups on cow dung.

COPROPHILOUS AGARICS FROM SOUTH INDIA

Natarajan and Raaman (1983, 1984) reported 14 mushrooms growing on dung from South India. Out of these, 05 species belong to the genus *Psilocybe*, 05 to *Panaeolus*, 03 to *Conocybe*, and 01 species to *Protostropharia.* From amongst the species documented *Psilocybe aztecorum* R. Heim, *P. argentina* (Speg.) Singer, and *P. gigaspora* Natarajan & Raaman were reported to be associated with cow dung; *P. coprophila* (Bull.) P. Kumm. on mixed dung and *P. cubensis* (Earle) Singer on elephant dung and manure. *Panaeolus africanus* Oláh, *P. antillarum* (Fr.) Dennis, *P. annulatus* Natarajan & Raaman, *P. subbalteatus* (Berk. & Br.) Sacc. and *P. cyanescens* (Berk. & Br.) Sacc. were reported from elephant dung; *Conocybe ambigua* Watling, *C. semiglobata* Kühner & Watling, and *Pholiotina plumbeitincta* (G.F. Atk.) Hauskn., Krisai & Voglmayr from cow dung; and *Protostropharia semiglobata* (Batsch) Redhead, Moncalvo and Vilgalys on unspecified dung.

Bhavani Devi (1995) enlisted 134 taxa known from Kerala, a state on India's tropical Malabar Coast. Out of these 134 taxa, 13 taxa have been reported to occur in coprophilous habitats. These are *Amanita solitaria* (Bull.) Mérat from cow dung heaps; *Bolbitius vitellinus* on dung; *Conocybe antipus* (Lasch) Fayod on manure and compost heaps; *Coprinopsis nivea* (Pers.) Redhead, Vilgalys & Moncalvo from cow dung; *C. radiata* (Bolton) Redhead, Vilgalys & Moncalvo from dung heaps; *Panaeolus semiovatus* (Sowerby) S. Lundell & Nannf. from elephant dung; *Panaeolus solidipes* (Peck) Sacc. from manured ground; *P. ater* (J.E. Lange) Kühner and Romagn. ex Bon from the droppings of herbivorous animals; *Leucocoprinus cepistipes* (Sowerby) Pat. from manured ground on humus rich soil; *Psilocybe coprophila* (Bull.) P. Kumm. from elephant dung; *Protostropharia semiglobata* (Batsch) Redhead; Moncalvo & Vilgalys from dung or manured soil; *Volvopluteus gloiocephalus* (DC.: Fr.) Vizzini; Contu and Justo from manured ground; *Chlorophyllum molybdites* (G. Mey.) Massee from the basins of plants where manuring is done.

Vrinda *et al.* (1999) reported *Panaeolus acuminatus* Quél. and *Parasola conopilus* (Fr.) Örstadius & E. Larss. growing scattered on elephant dung from Kerala. Thomas *et al.* (2001) documented *Bolbitius coprophilous* (Peck) Hongo, *Conocybe pseudopubescens* K. A. Thomas, Hauskn. & Manimohan and *C. volvata* K. A. Thomas, Hauskn. & Manim. growing on elephant dung and *C. zeylanica* (Petch) Boedijn on the heap of dried cow dung from Kerala. Thomas and Manimohan (2002) reported 05 coprophilous species of *Psilocybe* from Kerala state. These are *P. argentina* (Speg.) Singer from cow dung; *P. coprophila* (Bull.) P. Kumm., *P. subaeruginascens* Höhn and *P. subcubensis* Guzmán from elephant dung and *P. cubensis* (Earle) Singer from the manured soil with heavy traffic of cattle. Thomas and Manimohan (2003) documented *Agrocybe guruvayoorensis* K. A. Thomas & Manim. growing on elephant dung during the months of July-October in Kerala state. Manimohan *et al.* (2007) documented 19 species representing 12 genera and 05 agaric families associated with dung of both wild and domesticated elephants from Kerala state. These are *Agrocybe guruvayoorensis* K. A. Thomas & Manim.; *Bolbitius coprophilous* (Peck) Hongo; *Conocybe brunneoaurantiaca* K. A. Thomas, Hauskn. & Manim.; *C. pseudopubescens* K. A. Thomas, Hauskn. and Manimohan; *C. volvata* K. A. Thomas, Hauskn. & Manim.; *Crucispora rhombisperma* (Hongo) E. Horak; *Entoloma anamikum* Manim.; A. V. Joseph & Leelav.; *Macrocybe gigantea* (Massee) Pegler & Lodge; *Panaeolus antillarum* (Fr.) Dennis; *P. cyanescens* (Berk. & Br.) Sacc.; *P. rickenii* Hora; *Pholiotina indica* K. A. Thomas, Hauskn. & Manim.; *Psilocybe coprophila* (Bull.) P. Kumm.; *P. pegleriana* Guzmán; *P. subaeruginascens* Höhn; *P. subcubensis* Guzmán; *Stropharia bicolor* Pegler; *S. rugosoannulata* Farl.: Murrill and *Volvariella volvacea* (Bull.) Singer. Noordeloos *et al.* (2007) documented the occurrence of *Crucispora rhombisperma* (Hongo) E. Horak on the elephant dung from Kerala state. Arun Kumar and Manimohan (2009) recorded *Leucocoprinus pusillus* T.K.A. Kumar & Manim. growing on manure rich soil from Kerala state.

COPROPHILOUS AGARICS FROM EASTERN INDIA

Bose (1920) reported *Coprinellus fimbriatus* (Berk. & Br.) Redhead,Vilgalys & Moncalvo and *Panaeolus cyanescens* (Berk. & Br.) Sacc. growing on herbivorous dung from West Bengal in eastern India. Dhancholia and Sinha (1990) recorded two coprophilous mushrooms, *viz*. *Leucoagaricus meleagris* (Gray) Singer and *Leucocoprinus cepistipes* (Sowerby) Pat. growing on cow dung from Odisha, located in eastern India.Verma *et al.* (1995) found *Lepiota leprica* (Berk. & Br.) Sacc. growing solitary or in groups in open fields and pastures on cow dung or organic matter rich soil in North-East Hills. Andheria (2012a) reported an unnamed mushroom growing on elephant dung from Pakke Tiger Reserve, Arunachal Pradesh.

COPROPHILOUS AGARICS FROM WESTERN INDIA

Karun and Sridhar (2015) documented five species belonging to four genera of *Agaricales* growing on elephant dung in the Brahmagiri Wildlife Sanctuary of Western Ghats of Karnataka in the south western region of India. These were *Conocybe pubescens* (Gillet) Kühner, *Coprinopsis patouillardii* (Quél.) G. Moreno, *Panaeolus fimicola* (Pers.) Gillet, *Psilocybe coprophila* (Bull.) P. Kumm. and *P. fimetaria* (P.D. Orton) Watling. Andheria (2012b) reported an unnamed mushroom growing on Nilgai dung in Umred Karhandla Wildlife Sanctuary, Maharashtra. Andheria (2012c) reported an unnamed mushroom growing on elephant dung from BRT Tiger Reserve, Karnataka.

RELEVANCE OF COPROPHILOUS AGARICS

The fascination of humans for mushrooms growing on dung goes back to the earliest times. In their search for edible foods, early hunter-gatherers followed the manure trails of the large migratory herds. Being hungry and curious, early humans commonly consumed the small meaty mushrooms, some of which were psychoactive. Some such mushrooms commonly occurring on the dung of ruminants were species of various agaricoid genera including *Psilocybe, Panaeolus*, etc. Many of these mushrooms were largely valued not only as food sources, but for the expansion of consciousness and perception they induced. Over the years, substantial knowledge has accumulated about the use of mushrooms, their recipes and effects. Archeological records suggest that early humans knew about mushrooms' special effects and because of this they consumed them intentionally especially during the festive seasons. Several writers have suggested that major religious ideas were inspired by the intake of such entheogenic mushrooms and plants (Lowy and Wasson, 1969; Arthur, 2000; Allen and Arthur; 2003).

The information about their human relevance is compiled in **Table 2**. It is based on the literature and no personal observations were made in this regard.

DISCUSSION

The data given in this overview is an attempt to compile and provide updated information regarding the diversity and utility of coprophilous agarics at one place which otherwise is lying scattered in literature. It appears that, despite the effort and the information, there is still a long way to go in terms of developing a basic knowledge about the diversity of the mycota growing on animal dung. The work, perhaps, cover only a part of the actual diversity of these mushrooms the world over as most of the relevant original information is literature-based and many of the papers bear only limited information on habit, habitat and economic potential. However, the knowledge generated by the work is of immense utility as it may serve as a key revealing the diversity and ecology of mushrooms which grow on herbivorous dung. The review demonstrates that dung is a significant substrate which serves as a favorable niche for the growth of a variety of mushrooms. Geographically, coprophilous mushrooms are distributed worldwide and most of them belong to the families *Agaricaceae, Psathyrellaceae* and *Strophariaceae*.

The coprophilous agarics play a significant role in the sustenance of ecological balance on the earth. But throughout the world the natural habitats with dung deposits such as pastures, grasslands, open fields, etc. are getting destroyed because of the various developmental activities. As a result, most of the coprophilous taxa may be in danger of getting extinct. Their ecological relationships with their herbivorous

Table 1. Some reports about documentation of agaricoid coprophilous mushroom genera (Nomenclature Source MycoBank).

Family	Recorded Genera	References
Agaricaceae Chevall.	***Agaricus*** L.: Fr.	Srivastava (1978), Kannaiyan and Ramasamy (1980), Purkayastha and Chandra (1985), Saini and Atri (1995), Kaur *et al.* (2014b), Amandeep *et al.* (2015b,d)
	Chlorophyllum Massee	Manjula (1980), Natarajan and Manjula (1981), Bhavani Devi (1995), Amandeep *et al.* (2015d)
	Coprinus Pers.	Rea (1922), Mahju (1933), Ginai (1936), Van de Bogart (1976, 1979), Pegler (1977, 1986), Arora (1986), Uljé and Bas (1988, 1991), Kaushal and Grewal (1992), Uljé and Noordeloos (1993, 1997, 1999), Jordon (1995), Saini and Atri (1995), Richardson and Watling (1997), Richardson (2001a), Atri and Kaur (2004), Keirle *et al.* (2004), Richardson (2004), Doveri (2010), Prydiuk (2010), Amandeep *et al.* (2015b,d), Singh *et al.* (2018).
	Crucispora E. Horak	Manimohan *et al.* (2007), Noordeloos *et al.* (2007), Amandeep *et al.* (2015d)
	Cyathus Haller	Richardson (2001a)
	Lepiota (Pers. ex Fr.) S.F. Gray	Arora (1986), Dhancholia and Sinha (1990), Jordon (1995), Verma *et al.* (1995), Amandeep *et al.* (2015b,d)
	Leucoagaricus (Locquin) Sing.	Manjula (1980, 1983), Dhancholia and Sinha (1990), Bhavani Devi (1995), Amandeep *et al.* (2015d)
	Leucocoprinus Pat.	Patel and Kamat (1935), Rawla *et al*. (1982), Dhancholia and Sinha (1990), Bhavani Devi (1995), Saini and Atri (1995), Richardson and Watling (1997), Doveri (2010), Amandeep *et al.* (2015b,d)
	Podaxis Desv.	Keirle *et al.* (2004)
Amanitaceae R. Heim: Pouzar	***Amanita*** Pers.	Bhavani Devi (1995), Amandeep *et al.* (2015d)
Bolbitiaceae Sing.	***Bolbitius*** Fr.	Rea (1922), Mahju (1933), Singer (1977), Pegler (1977, 1986), Watling (1982), Arora (1986), Jordon (1995), Saini and Atri (1995), Richardson and Watling (1997), Thomas *et al.* (2001), Manimohan *et al.* (2007), Doveri (2010), Watling and Richardson (2010), Amandeep *et al.* (2013b, 2015d)
	Conocybe Fayod	Pegler (1977), Watling (1982), Natarajan and Raaman (1983, 1984), Sarwal and Rawla (1983), Arora (1986), Watling and Taylor (1987), Bhavani Devi (1995), Saini and Atri (1995), Richardson and Watling (1997), Thomas *et al.* (2001), Hausknecht *et al.* (2005), Hausknecht and Contu (2007), Manimohan *et al*. (2007), Atri *et al.* (2009, 2012), Doveri (2010), Watling and Richardson (2010), Karun and Sri dhar (2015), Amandeep *et al.* (2015 a,d)
	Panaeolina Maire	Noordeloos *et al.* (2007)
	Pholiotina Fayod	Natarajan and Raaman (1983, 1984), Watling and Taylor (1987), Thomas *et al.* (2001), Manimohan *et al.* (2007), Amandeep *et al.* (2015d)
	Pluteolus (Fr.) Gillet	Singer (1977)
Entolomataceae Kotlába & Pouzar	***Clitopilus*** (Fr. ex Rabenh.) P. Kumn.	Watling and Richardson (2010)
	Entoloma Fr.: Kummer	Thomas *et al.* (2001), Manimohan *et al.* (2007), Amandeep *et al.* (2015d)
	Rhodocybe Maire	Kaur *et al.* (2013a), Amandeep *et al.* (2015d)
Lyophyllaceae Jülich	***Termitomyces*** R. Heim	Amandeep *et al.* (2015d)
	Calocybe Kühner ex Donk	Vishwakarma *et al.* (2017)
Mycenaceae Overeem	***Mycena*** (Pers.) Roussel	Amandeep *et al.* (2013b, 2015d)
Pluteaceae Kotl. and Pouzar	***Volvariella*** Speg.	Richardson and Watling (1997), Manimohan *et al.* (2007), Doveri (2010), Amandeep *et al.* (2015d)
	Volvopluteus Vizzini, Contu and Justo	Bhavani Devi (1995), Dutta *et al.* (2011), Amandeep *et al.* (2015d)
Psathyrellaceae Vilgalys, Moncalvo and Redhead	***Coprinellus*** P. Karst.	Bose (1920), Rea (1922), Mahju (1933), Lange and Smith (1953), Van de Bogart (1976), Pegler (1977,1986), Manjula (1983), Arora (1986), Uljé and Bas (1988, 1991), Uljé and Noordeloos (1993, 1997, 1999), Jordon (1995),Saini and Atri (1995), Richardson and Watling (1997), Richardson (2001a), Atri and Kaur (2004), Keirle *et al.* (2004), Richardson (2004), Doveri (2010), Prydiuk (2010), Watling and Richardson (2010), Amandeep *et al.* (2015d)
	Coprinopsis P. Karst.	Lange and Smith (1953), Van de Bogart (1976), Pegler (1977, 1986), Arora (1986), Uljé and Bas (1988, 1991), Uljé and Noordeloos (1993, 1997, 1999), Bhavani Devi (1995), Jordon (1995), Richardson and Watling (1997), Richardson (2001a), Atri and Kaur (2004), Keirle *et al.* (2004), Richardson (2004), Doveri (2010), Prydiuk (2010), Watling and Richardson (2010), Amandeep *et al.* (2014, 2015b,d), Karun and Sridhar (2015)
	Panaeolus (Fr.) Quél.	Bose (1920), Pegler (1977), Natarajan and Raaman (1983, 1984), Watling and Taylor (1987), Watling and Gregory (1987), Bhavani Devi (1995), Jordon (1995), Stamets (1996), Richardson and Watling (1997), Vrinda *et al.* (1999), Manimohan *et al.* (2007), Doveri (2010), Watling and Richardson (2010), Amandeep *et al.* (2013a, 2015d), Kaur *et al.* (2014a,c), Karun and Sridhar (2015), Al-Khesraji, (2018); Toma *et al.,* (2018).
	Parasola Redhead, Vilgalys & Hopple	Pegler (1977), Watling and Taylor (1987),Vrinda *et al.* (1999), Keirle *et al.* (2004), Doveri (2010), Prydiuk (2010), Watling and Richardson (2010), Amandeep *et al.* (2015d)
	Psathyrella Fr.: Quél.	Richardson and Watling (1997), Larsson a and Örstadius b (2008), Doveri (2010), Kaur *et al.* (2013b, 2014c), Amandeep *et al.* (2015d)
Strophariaceae Singer & Smith	***Agrocybe*** Fayod	Pegler (1977), Singer (1977), Rawla *et al.* (1982), Watling (1982), Arora (1986), Saini and Atri (1995), Richardson and Watling (1997), Thomas and Manimohan (2003), Manimohan *et al.* (2007), Doveri (2010), Watling and Richardson (2010), Kaur *et al.* (2014d), Amandeep *et al.* (2015d)
	Protostropharia Redhead, Moncalvo & Vilgalys	Rea (1922), Ginai (1936), Pegler (1977), Natarajan and Raaman (1983), Arora (1986), Watling and Taylor (1987), Bhavani Devi (1995), Jordon (1995), Saini and Atri (1995), Richardson and Watling (1997), Watling and Richardson (2010), Doveri (2010), Kaur *et al.* (2013c), Amandeep *et al.* (2015d)
	Psilocybe (Fr.) P. Kumm.	Massee (1901), Pegler (1977, 1986), Natarajan and Raaman (1983, 1984), Arora (1986), Watling and Taylor (1987), Watling and Gregory (1987), Bhavani Devi (1995), Jordon (1995), Stamets (1996), Richardson and Watling (1997), Thomas and Manimohan (2002), Richardson (2004), Manimohan *et al.* (2007), Doveri (2010), Watling and Richardson (2010), Karun and Sridhar (2015), Amandeep *et al.* (2015d)
	Stropharia (Fr.) Quél.	Pegler (1977), Arora (1986), Watling and Taylor (1987), Watling and Gregory (1987), Jordon (1995), Richardson and Watling (1997), Manimohan *et al.* (2007), Doveri (2010), Watling and Richardson (2010), Amandeep *et al.* (2015d)
Tricholomataceae R. Heim: Pouzar	***Clitocybe*** (Fr.)	Richardson and Watling (1997), Watling and Richardson (2010)
	Lepista (Fr.) W.G. Sm.	Richardson and Watling (1997), Doveri (2010)
	Macrocybe Pegler & Lodge	Manimohan *et al.* (2007), Amandeep *et al.* (2015d)

Table 2. Relevance of Coprophilous Mushrooms

Characteristic	Name of the coprophilous taxa	References
Mushrooms with edibility potential	*Agaricus bernardii, A. campestris, A. placomyces, A. cupreobrunneus, A. halophilus, Coprinus comatus, Coprinus sterquilinus, Coprinopsis cinerea, Coprinellus micaceus, Chlorophyllum rhacodes, Leucoagaricus naucinus, Panaeolus acuminatus, P. rickenii, P. semiovatus , P. solidipes Protostropharia semiglobata, Volvopluteus gloiocephala,* and *Termitomyces radicatus.*	Kauffman (1918), Murrill (1922), Bose and Bose (1940), Atkinson 1961, Kaul and Kachroo (1974), Pegler (1977, 1983), Pegler and Piearce (1980), Purkayastha and Chandra (1985), Arora (1986), Singer (1986), Stamets (1996), Atri *et al.* (2007, 2009b), Amandeep *et al.* (2015c), Kaur *et al.* (2016)
	Coprinopsis atramentaria is particularly interesting since it is edible unless consumed with alcohol.	Bresinsky and Besl (1990)
	Coprinellus micaceus is considered ideal for omelettes, and as a flavor for sauces.	http://en.wikipedia.org/wiki/*Coprinellus_micaceus*
	Panaeolus acuminatus It has been listed to make a good strawberry milkshake.	Singer (1986)
Inedible and poisonous mushrooms	*Agaricus xanthodermus, Conocybe albipes, Chlorophyllum molybdites, Leucocoprinus cepistipes, Lepiota xanthophylla, L. subincarnata* are not worth consideration for human consumption. They are reported to be inedible and poisonous in literature.	Arora (1986), Singer (1986), Kerrigan (1986), Hall (2003), Vellinga (2001, 2003), Hallen *et al. (*2003)
	Symptoms of *Chlorophyllum molybdites* poisoning are reported to occur about 1-3 hours after the meal and persist for up to six hours or even longer.	Vellinga (2003), Kuo (2005)
	Lepiota subincarnata has been reported to be very toxic because of the presence of amanitins and amatoxins and its consumption is reported to be potentially lethal.	Vellinga (2001), Hall (2003)
Mushrooms with potential medicinal utility	*Coprinus comatus*, *Coprinopsis radiata, C. lagopus* and *Coprinellus micaceus* are reported to possess antibiotic properties against bacteria and fungi.	Ohtsuka*et al.* (1973), Botton and Siehr (1975), Efremenkova*et al.* (2001), Zenkova*et al.* (2003)
	Coprinus comatus has antidiabetic, antifungal and antibacterial properties.	Efremenkova *et al.* (2001), Zenkova *et al.* (2003)
	Coprophilus macrofungi (*Coprinus comatus*, *C. plicatilis*, and *C. cinereus*) are the producers of several bioactive metabolities (tri-sesquiterpenes, quinones, glucans, proteins, etc.) and enzymes (protease, phenoloxidases, etc.) with immune modulating, antifungal, antioxidant, thrombolytic, hypoglycemic and anti-protozoal effects and these metabolites can be extracted and identified. Polysaccharides extracted from the mycelial culture of *C. cinereus* have been shown to contain anti tumour effects. The polysaccharides obtained from *C. comatus*, tested in mice, revealed hypolipidemic effects and antioxidant properties suggesting that their antioxidant activity could be directly or indirectly responsible for its hypoglycemic and hypolipidemic properties.	Manoharachary *et al.* (2014)
	Tanzanian *C. cinereus* grown on dried grasses supplemented with cow dung manure exhibits activity against *Escherichia coli*, *Aspergillus niger* and *Candida albicans*.	Mwita *et al.* (2010)
	Coprinopsis radiata is reported to have antimicrobial and anticancer action.	Anisova *et al.* (1987)
	Coprinopsis quadrifidus has been reported to produce an antibiotic called quadrifidin.	Singer (1986)
	Coprinellus micaceus has been reported to possess antibacterial and antibiotic properties. The species also possesses a unique chemical sterol 'Micaceol' with potential for use in cancer chemotherapy.	Zahid *et al.* (2 006)
	Chlorophyllum molybdites, although produces ill effects in many individuals, has been reported to contain 08 steroidal derivatives, two of which are reported to be important in the treatment of human gastric cancer, besides possessing antitumor and antiviral components.	Chang and Hayes (1978), Didukh *et al.* (2004)
	Agaricus campestris is reported to be used for the treatment of ulcers, and bed sores.	http://en.wikipedia.org/wiki/*Agaricus_campestris*
	Beside these taxa, *Lepiota* and *Leucocoprinus* are the other commonly found genera in the coprophilous habitats which are reported to possess bioactive compounds with scope for utilization in human welfare.	Didukh *et al.* (2004)
Psychoactive/ Hallucinogenic properties	The most famous hallucinogenic mushrooms belong to *Psilocybe* and *Panaeolus.*	Stamets (1996), Allen and Gartz (1997), Guzmán *et al.* (2000), Trappe (2005)
	Coprophilous *Psilocybe aztecorum, P. cubensis, P. coprophila , P. mexicana, P. natalensis, P. semilanceata,* are known to have hallucinogenic properties. Some hallucinogenic species of *Panaeolus,* namely *P. africanus, P. acuminatus, P. antillarum, P. ater, P. castaneifolius, P. cyanescens, P. pa pilionaceus* var. *parvisporus, P. sphinctrinus, P. subbalteatus,* and *P. tropicalis* are reported to grow throughout the world on dung and well manured grounds.	Guzmán (1978), Margot and Watling (1981), Singer (1986), Stamets (1996) Allen and Gartz (1997)
Ecological aspect	Coprophilous Mushrooms play a significant role in the decomposition of the fecal materials, carbon flow and ecosystem energetics.	Angel and Wicklow (1974, 1975)
	Responsible for recycling the nutrients in animal faeces and in the formation of soil.	Kumar *et al.* (1995)
	An important source of nutrients for coprophagous and mycophagous arthropods.	Halfter and Matthew (1971)
Industrial use	*C. atramentaria* has been reported to be the main source of *Coprinus* ink which had utility for retouching work in photography and for specific effects in writing and drawing.	Singer (1986)

hosts must be conserved and attention be given to the study of these fungi which otherwise play a major role as natures recyclers and replenishers. More consideration should be given to rarely investigated habitats, as zoological reserves, studs, pastures or compost piles where many ink-cap species new to science or uncommonly recorded can found out.

CONCLUSION

As is apparent from the above account, the field of coprophilous mushrooms remains largely underexplored. There are many areas which are still unexplored from taxonomic and sociobiological point of view. So as to update and strengthen the knowledge about their occurrence, distribution and importance, a co-rdination amongst the mushroom mycologists on a wider scale is needed. The mycologists from throughout the world need to come together so as to undertake investigations for inventorization of these mushrooms by surveying the various dung localities and evaluate these for their nutritional and nutraceutical constituents. So as to identify edible and medicinally important mushrooms, sociobiological aspects of these mushrooms need to be explored by coordinating with the local inhabitants who are regularly using these mushrooms in their day to day life.

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