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# Ecology, Distribution Perspective, Economic Utility and Conservation of Coprophilous Agarics (*Agaricales*, Basidiomycota) Occurring in Punjab, India

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**Abstract**

This paper includes the results of eco-taxonomic studies of coprophilous mushrooms in Punjab, India. The information is based on the survey to dung localities of the state during the various years from 2007-2011. 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 recorded with the present study. The observed collections belong to 95 species spread over 20 genera and 07 families of the order *Agaricales*. The present paper discusses the distribution of these mushrooms in Punjab among different seasons, regions, habitats, and growing habits along with their economic utility, habitat management and conservation. This is the first attempt in which various dung localities of the state has been explored systematically to ascertain the diversity, seasonal availability, distribution and ecology of coprophilous mushrooms. The study has shown that dung is an important substrate which serves as a favorable niche for the growth of a variety of mushrooms.

**Key words** – Abundance – biodiversity – herbivorous dung – seasonal availability

## Introduction

The coprophilous fungi represent a diverse group of saprobes including taxa from most major fungal groups belonging to *Zygomycota, Ascomycota* and *Basidiomycota* (Kumar *et al.* 1995). The present work, however, has been focused on the basidiomycetous coprophilous lamellate mushrooms belonging to the order *Agaricales*. The coprophilous mushrooms reported world over are known to occur more frequently on dung of herbivores than carnivores (Webster 1970, Kumar *et al.* 1995). The carnivorous dung is quite rich in proteins and is decomposed by bacteria and some insects (Bell 1983, Richardson 2001). As compared, the herbivorous dung requires fungi for its decomposition as cellulose and lignin forms the major proportion which are quite complex in architecture (Webster 1970).

Herbivorous dung has been reported to contain the macerated 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

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(Lambourne & Reardon 1962). It is also reported to contain a large amount of readily available carbohydrates (Richardson 2001). The physical structure, pH and high moisture contents of dung are reported to be the major contributing factors for its suitability for the growth of coprophilous fungi (Morrison 1959, Lodha 1974).

The nature of herbivorous 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 (Ing 1989, Richardson 1998, 2003). Since the great variation in the feeding habits, habitats, and digestive systems of herbivores, a variety of fungi in general and mushrooms in particular are documented to grow indiscriminately on any herbivore dung. The greatest variety of coprophilous fungi has been reported on cow, horse, and rabbit dung, primarily because the majority of research has remained focused on the dung of these animals only (Bell 1983).

The world over studies on coprophilous fungi suggested that this group plays an important role in the decomposition of the fecal materials, carbon flow and ecosystem energetics (Angel and Wicklow 1974, 1975). These are also considered as an important source of nutrients for coprophagous and mycophagous arthropods (Halfter & Matthews 1971). They are responsible for recycling the nutrients in animal faeces and in the formation of soil (Kumar *et al.* 1995).

During the past four decades much progress has been achieved in the field of mushroom research in India. A review of literature on taxonomy and diversity of agarics reveals that about 1500 species belonging to 140 genera have been reported from India (Sathe & Rahalkar 1978, Sathe & Deshpande 1980, Bilgrami *et al.* 1979, 1991, Jamalludin *et al.* 2001, Atri & Kaur 2004; Atri & Kour 2005, Atri *et al.* 2005, 2009a,b, 2010, Natarajan *et al.* 2005, Manimohan *et al.* 2007, Noordeloos *et al.* 2007, Gupta *et al.* 2008a, b, Saini *et al.* 2008-2009, Kumar & Manimohan 2009, Kaur *et al.* 2008, 2011a, b, Dutta *et al.* 2011, Pushpa & Purushothama 2011, 2012, Farook *et al.* 2013, Kumar *et al.* 2014). But as far as coprophilous mushrooms are concerned, only a few articles (Rea 1922, Mahju 1933, Ginai 1936, Rawla *et al.* 1982, Dhancholia & Sinha 1990, Kaushal & Grewal 1992, Vrinda *et al.* 1999, Thomas *et al.* 2001, Manimohan *et al.* 2007, Atri *et al.* 2009a, 2012, Dutta *et al.* 2011, Amandeep *et al.* 2013 a,b, 2014, 2015a,b, Kaur *et al.* 2013 a,b,c, 2014a,b,c, Karun & Sridhar 2015) have been published so far. Whatever little information we have from India is in the form of scattered sketchy reports representing about 80 mushrooms growing on dung.

In view of this, an attempt has been made to investigate the diversity of coprophilous mushrooms of Punjab as the state is primarily an agrarian state and has a marked variety of animal population under domestication. Also, the striking variation in climate also plays a determinate role in growth and development of wide variety of mushrooms including coprophilous mycoflora.

**Materials & Methods**

Study Area – The Punjab state with an averge altitude of ~300 masl lies at 29º32'–32º32'N 73º55'–76º70’E in the north-western part of India and it covers an area of 50,362 sq km that constitutes 1.57% of the total area of country. Climatically, Punjab has four major seasons- summer, monsoon, winter and autumn season. The amount of rainfall in Punjab ranges between 250–1000 mm. Most of the annual rainfall is experienced during the arrival of southwest monsoon in the region. About 70-80% of the total rainfall is concentrated during July, August and September and the rest occurs during the winter months. The study area has seven to eight months of mean monthly temperature of more than 20˚C. It is primarily an agrarian state having diverse flora and fauna. Various domesticated and wild herbivorous animals are found on the grazing lands of the state. Of the total livestock, about 90% are cattle and buffaloes and the rest sheep, goats, camels, donkeys, mules and other animals which are domesticated for their use in agriculture, dairy, transportation and various other purposes.

The state has 22 districts in all. In the present investigation, different dung localities from 16 districts, namely Tarn Taran (169 m), Ferozepur (182 m), Faridkot (196 m), Bathinda (211 m), Moga (217 m), Kapurthala (224 m), Fatehgarh Sahib (228 m), Barnala (228 m), Sangrur (231 m), Jalandhar (233 m), Patiala (251 m), Ludhiana (254 m), Hoshiarpur (295 m), Pathankot (309 m), Mohali (316 m)

and Ropar (394 m) have been explored for the collection of material during the years 2007-2011**(Fig. 1).** These localities include majority of the Punjab plains and a part of the sub-mountainous zone of the Shivalik hills.

The present investigation has been focused on the mushrooms growing on dung of herbivorous livestock- mostly that of cattle, buffaloes, horses, camels, goats and sheep which covers the domesticated animal population of Punjab. For the purpose of mushroom collection, frequent fungal forays were also undertaken to the dung localities of Zoos and Wildlife Sanctuaries, etc. which are situated in the area under investigation. The various coprophilous habitats of the state include dung deposits in the pastures, wastelands, and dung heaps in farms, along roadsides, etc. **(Fig. 2).**

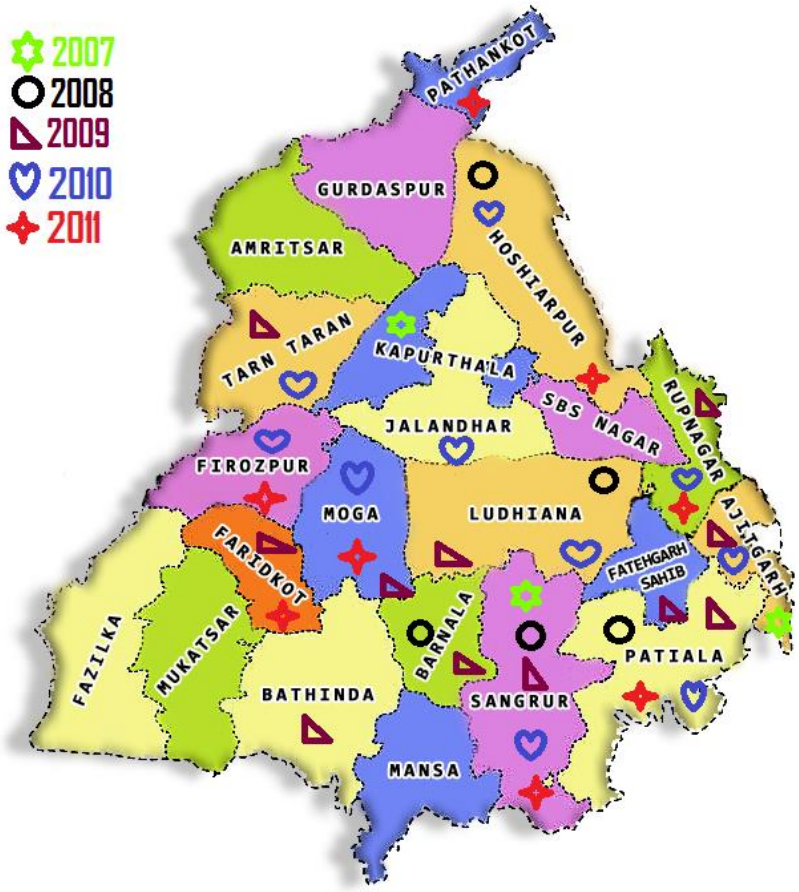


**Fig. 1** – Sample collection localities in Punjab.*Source: www.Probharat.com

Observation and Identification – All the descriptions are based on the specimens collected from different dung localities in Punjab. The standard methods are applied for species identification, including macroscopic and microscopic characters (Kornerup & Wanscher 1978, Singer 1986, Atri *et al.* 2005a). The examined collections have been deposited in the Herbarium of Punjabi University Patiala, Punjab under PUN. The following keys and monographs have been used as resources for determination of the coprophilous taxa presently investigated – Rea (1922), Smith (1949, 1972), Shaffer (1957), Pegler (1977, 1983, 1986), Van de Bogart (1976, 1979), Sundberg (1971, 1989), Natarajan & Raaman (1983, 1984), Singer (1986), Arora (1986), Watling (1982, 1985), Watling & Bigelow (1983), Watling & Gregory (1987), Watling & Taylor (1987), Uljé & Bas (1988, 1991), Uljé & Noordeloos (1993, 1997, 1999), Stamets (1996), Moncalvo *et al.* (2000, 2002), Noordeloos *et al.* (2005), Matheny *et al.* (2006), Prydiuk (2007a,b), and Hausknecht *et al.* (2009), etc. During the present investigation, classification and authentic names of the investigated taxa are as per the latest version of Dictionary of Fungi (Kirk *et al.* 2008) and the information available on MycoBank (http://www.mycobank.org/MycoTaxo.aspx) and Species Fungorum (www.speciesfungorum.org) websites.


**Fig. 2** – Various types of coprophilous habitats of Punjab. A Harpalpur, Patiala. B Bajakhana, Faridkot. C Siprian, Hoshiarpur. D Qila Rehmatgarh, Sangrur. E Lohatbaddi, Ludhiana. F Mudki, Ferozepur.

## Results

In this work, 172 collections have been thoroughly examined for their macroscopic, microscopic, chemical reactions, and ecological details. These collections belong to 95 species and 20 genera spread over 07 families of order *Agaricales*. The distribution of these coprophilous mushrooms among different seasons, regions, habitats, and growing habits, etc. has been summarized in **Table 1.**

**Table 1** Diversity of investigated coprophilous agarics

| Sr. No. | Taxa | Ecology & Distribution |
|---|---|---|
| **I.** | **Agaricaceae** Chevall. | |
| **i.** | ***Agaricus*** L.: Fr. | |
| 1. | *A. campestris* L. | Sangrur (231m), Qila Rehmatgarh, growing in caespitose groups on mixed cattle dung, Amandeep Kaur, PUN 4772, June 22, 2008; Ferozepur (182 m), Sodhinagar, growing scattered on buffalo dung, Amandeep Kaur, PUN 4773, August 16, 2011. |

| Sr. No. | Taxa | Ecology & Distribution |
|---|---|---|
| 2. | *A. cupreobrunneus* (Schäffer & Steer: Møller) Pilát | Sangrur (231m), Fatehgarh Channa, growing scattered in a fairy ring on mixed cattle dung alongwith earthworm excreta, Amandeep Kaur, PUN 4213, July 25, 2010. |
| 3. | *A. flavistipus* Atri, M. Kaur and A. Kaur | Faridkot (196 m), Swaag, growing solitary on buffalo dung, Amandeep Kaur, PUN 4774, August 19, 2011. |
| 4. | *A. halophilus* Peck | Mohali (316 m), Dau Majra, growing scattered on mixed cattle dung heap, Amandeep Kaur, PUN 4211, July 10, 2010; Sangrur (231 m), Daulatpur Channa, growing in groups on buffalo dung, Amandeep Kaur, PUN 4212, July 25, 2010. |
| 5. | *A. placomyces* Peck | Patiala (251m), Chhat Bir, growing solitary on deer dung, Amandeep Kaur, PUN 4775, September 19, 2011. |
| 6. | *A. pratensis* Schaeff. | Sangrur (231m), Jamalpura, growing in groups on mixed cattle dung, Amandeep Kaur, PUN 4210, June 22, 2008. |
| 7. | *A. stellatus-cuticus* Atri, M. Kaur and A. Kaur | Sangrur (231m), Qila Rehmatgarh, growing solitary on sheep dung among plant debris, Amandeep Kaur, PUN 4776, September 19, 2011. |
| 8. | *A. xanthodermus* Genevier | Sangrur (231 m), Sandaur, growing scattered on mixed cattle dung, Amandeep Kaur, PUN 4777, September 28, 2008; AahanKhaeri, growing scattered on mixed cattle dung, Amandeep Kaur, PUN 4778, June 27, 2011. |
| **ii.** | ***Chlorophyllum*** Massee | |
| 9. | *C. molybdites* (G. Mey.) Massee | Sangrur (231 m): Qila Rehmatgarh, growing scattered in a group on camel dung, Amandeep Kaur, PUN 4779, September 27, 2010; Hoshiarpur (295 m), Jattpur, growing gregariously on buffalo dung, Amandeep Kaur, PUN 4780, July 05, 2011; Ropar (394 m), Bairampur, growing scattered on mixed cattle dung heap, Narinderjit Kaur, PUN 4682, August 22, 2011. |
| 10. | *C. rhacodes* Vellinga | Moga, Chak Fatehpur, growing in a fairy ring on buffalo dung, Amandeep Kaur, PUN 4781, June 28, 2011. |
| **iii.** | ***Coprinus*** Pers. | |
| 11. | *C. comatus* var. *caprimammillatus* Bogart | Sangrur (231 m), Qila Rehmatgarh, solitary to densely grouped on mixed cattle dung in a pasture, Amandeep Kaur, PUN 4061, June 03, 2008; Bathinda (211 m), Naruaana, growing in groups on mixed cattle dung, Amandeep Kaur, PUN 4782, August 01, 2009. |
| 12. | *C. comatus* var. *comatus* (Müll.: Fr.) Gray | Moga (217 m), Ajitwal, growing scattered on mixed cattle dung, Amandeep Kaur, PUN 4783, August 13, 2010. |
| 13. | *C. cordisporus* T.Gibbs | Hoshiarpur (295m): Satiana, growing in groups on mixed cattle and horse dung heap, Amandeep Kaur, PUN 4784, July 14, 2010. |
| 14. | *C. sterquilinus* (Fr.) Fr. | Ludhiana (254 m), Lohatbaddi, growing solitary on horse dung, Amandeep Kaur, PUN 4785, June 10, 2008; Faridkot (196 m), Bajakhana, growing solitary on manured soil, Harwinder Kaur, PUN 4771, September 10, 2009; Sangrur (231 m), Sikanderpura, growing scattered on mixed cattle dung, Amandeep Kaur, PUN 4786, June 29, 2011. |
| **iv.** | ***Lepiota*** (Pers. ex Fr.) S.F. Gray | |
| 15. | *L. epicharis* var. *occidentalis* Dennis | Hoshiarpur (295 m), Shehbazpur Tanda, growing in a group on mixed buffalo dung and wheat straw heap, Munruchi Kaur and Amandeep Kaur, PUN 4787, September 03, 2011. |
| 16. | *L. humei* Murrill | Patiala (251 m), Shekhpura, growing gregariously on mixed cattle dung, Babita Kumari, PUN 4112, May 23, 2008; Punjabi University, growing scattered on mixed cattle dung, Babita Kumari, PUN 4110, May 27, 2008; Behal, growing in groups on mixed cattle dung, Amandeep Kaur, PUN 4065, June 16, 2008; Sangrur (231 m), Lasoi, growing in groups on manured ground, Amandeep Kaur, PUN 4207, June 17, 2008; Barnala (228 m), Sherpur, growing solitary on buffalo dung, |

| Sr. No. | Taxa | Ecology & Distribution |
|---|---|---|
| | | Amandeep Kaur, PUN 4066, June 26, 2008; Chhat Bir (251 m), growing solitary on buffalo dung, Amandeep Kaur, PUN 4067, June 30, 2008; Patiala (251 m), Punjabi University, growing scattered on cattle dung, Babita Kumari, PUN 4113, July 16, 2008; Punjabi University, growing gregariously on cattle dung, Babita Kumari, PUN 4115, August 12, 2008; Ludhiana (254 m), Seora, growing in groups on manured soil near mixed cattle dung heap, Amandeep Kaur, PUN 4068, July 25, 2009; Bathinda (251 m), Jassi Pau Wali, growing in groups on mixed cattle dung, Amandeep Kaur, PUN 4069, August 02, 2009; Patiala (251 m), Bahadurgarh, growing scattered on cattle dung, Babita Kumari, PUN 4097, August 18, 2009; Rajpura, growing in groups on cattle dung, Babita Kumari, PUN 4103, August 19, 2009. |
| 17. | *L. subincarnata* J.E. Lange | Sangrur (231 m), Qila Rehmatgarh, growing solitary on camel dung, Amandeep Kaur, PUN 4788, September 19, 2011. |
| 18. | *L. thiersii* Sundberg | Mohali (316 m), Bhajauli, growing in groups on buffalo dung heap, Amandeep Kaur, PUN 4070, August 21, 2009. |
| 19. | *L. thrombophora* (Berk. & Br.) Sacc. | Ropar (394 m): Mugal Majri, growing in groups on mixed cattle dung, Amandeep Kaur, PUN 4071, August 21, 2009. |
| 20. | *L. xanthophylla* P.D. Orton | Faridkot (196 m), Deena Kangar, growing scattered on buffalo dung, Amandeep Kaur, PUN 4789, August 19, 2011. |
| **v.** | ***Leucoagaricus*** (Locquin) Sing. | |
| 21. | *L. naucinus* (Fr.) Singer | Hoshiarpur (295 m), Jejon Duaba, growing gregariously forming a fairy ring on mixed cattle dung heap, Amandeep Kaur, PUN 4790, July 05, 2011. |
| **vi.** | ***Leucocoprinus*** Pat. | |
| 22. | *L. cepistipes* (Sowerby) Pat. | Ropar (394 m), Bhupnagar, growing scattered on mixed cattle dung heap, Amandeep Kaur, PUN 4208, July 10, 2010; Jallandhar (233 m), Kala Bakkra, growing in groups on buffalo dung, Amandeep Kaur, PUN 4209, July 30, 2010; Hoshiarpur (295 m): Mehlanwaali, growing in groups on mixed cattle dung, Amandeep Kaur, PUN 4791, July 05, 2011; Hoshiarpur (295 m), Jattpur, growing scattered on mixed cattle dung under *Acacia nilotica*, Narinderjit Kaur, PUN 4690, August 16, 2011; Hoshiarpur (295 m), Chaggran, growing scattered on mixed cattle dung, Narinderjit Kaur, PUN 4691, August 16, 2011. |
| 23. | *L. straminellus* (Bagl.) Narducci & Caroti | Patiala (251 m), Harpalpur, growing in groups on buffalo dung heap, Amandeep Kaur, PUN 4792, July 19, 2011. |
| **II.** | **Bolbitiaceae** Sing. | |
| **vii.** | ***Bolbitius*** Fr. | |
| 24. | *B. coprophilous* (Peck) Hongo | Sangrur (231 m), Bamaal, growing gregariously on buffalo dung flakes near village pond, Amandeep Kaur, PUN 4793, July 22, 2009; Haidernagar, growing scattered on buffalo dung, Amandeep Kaur, PUN 4794, June 29, 2011. |
| 25. | *B. demangei* (Quél.) Sacc. & Sacc. | Sangrur (231 m): Binzoki, growing in groups on buffalo dung and rotting Jute fabric, Amandeep Kaur, PUN 4795, June 29, 2011; Faridkot (196 m): Chandwaja, growing in a group on mixture of cattle dung and straw, Amandeep Kaur, PUN 4796, August 19, 2011. |
| 26. | *B. glatfelteri* Peck | Patiala (251 m), Bhedpura, growing scattered in a group on buffalo dung and leaf litter, Amandeep Kaur, PUN 4797, July 16, 2011. |
| 27. | *B. marginatipes* Zeller | Sangrur (231 m): Haidernagar, growing scattered on buffalo dung, Amandeep Kaur, PUN 4798, June 29, 2011. |
| 28. | *B. titubans* (Bull.) Fr. | Sangrur (251 m), Ratolan, growing solitary on buffalo dung, Amandeep Kaur, PUN 3896, September 29, 2008. |
| 29. | *B. vitellinus* Fr. | Sangrur (231 m), Alipur, growing solitary on buffalo dung heap, Amandeep Kaur, PUN 4214, June 08, 2008. |

| Sr. No. | Taxa | Ecology & Distribution |
|---|---|---|
| **viii.** | ***Conocybe*** Fayod | |
| 30. | *C. albipes* (G.H. Otth) Hausknecht | Chhat Bir (251 m), growing scattered in a group on elephant dung mixed with rotten wheat straw and leaf litter, Amandeep Kaur, PUN 4799, September 19, 2011. |
| 31. | *C. apala* (Fr.) Arnolds | Tarn Taran, Baath (169 m), growing solitary on buffalo dung, Amandeep Kaur, PUN 4219, July 31, 2010; Tarn Taran, Naushehra Pannua (169 m), growing in groups on buffalo dung, Amandeep Kaur, PUN 4220, August 02, 2010; Ferozepur, Makhu (182 m), growing in groups on buffalo dung, Amandeep Kaur, PUN 4230, August 02, 2010; Moga (217 m), Chak Kania Wala, growing scattered on mixed cattle dung, Amandeep Kaur, PUN 4344, June 28, 2011; Hoshiarpur (295 m), Shehbaazpur Tanda, growing scattered on mixed buffalo dung and wheat straw, Amandeep Kaur, PUN 4343, September 03, 2011. |
| 32. | *C. brachypodii* (Velen.) Hauskn. & Svrček | Patiala (251m), Mehmoodpur Jattan, growing in groups on mixed cattle dung heap, Amandeep Kaur, PUN 3899, June 14, 2008. |
| 33. | *C. crispa* (Longyear) Singer | Sangrur (231m), Upoki, growing in caespitose cluster on partially decomposed buffalo dung flake, Amandeep Kaur, PUN 3897, August 20, 2008. |
| 34. | *C. fuscimarginata* (Murrill) Singer | Patiala (251 m): Balbehra, growing in groups on cow dung, Amandeep Kaur, PUN 4350, June 25, 2008; Barnala (228 m): Farwahi, growing in groups on mixed cattle dung, Amandeep Kaur, PUN 4349, June 26, 2008. |
| 35. | *C. lenticulospora* Watling | Ludhiana (254 m), Lohatbaddi, growing in groups on mixed cattle dung, Amandeep Kaur, PUN 4347, July 14, 2008. |
| 36. | *C. leucopus* (Kühner) Kühner & Watling | Ferozepur (182 m), Mudki, growing scattered in a group on cow dung on ants' hill, Amandeep Kaur, PUN 4800, August 16, 2011. |
| 37. | *C. magnicapitata* P. D. Orton | Ferozepur (182 m), Sodhinagar, growing solitary on buffalo dung, Amandeep Kaur, PUN 4801, August 16, 2011. |
| 38. | *C. microrrhiza* var. *coprophila* Amandeep Kaur, Atri and Munruchi Kaur | Faridkot (196 m): Chandwaja, growing solitary on cow dung, Amandeep Kaur, PUN 4802, August 19, 2011. |
| 39. | *C. moseri* Watling | Moga (217 m), Ajitwal, growing scattered on mixed cattle dung, Amandeep Kaur, PUN 4352, August 13, 2010; Ludhiana (254 m): Lohatbaddi, growing in groups on mixed cattle dung, Amandeep Kaur, PUN 3898, July 14, 2008. |
| 40. | *C. rickenii* (Schaef.) Kühner | Sangrur (231 m), Jaatimajra, growing solitary on buffalo dung, Amandeep Kaur, PUN 4351, September 13, 2009. |
| 41. | *C. subpubescens* P. D. Orton | Hoshiarpur (295 m): Jalota Dasuya, growing scattered in a group on mixed horse dung and cattle dung heap mixed with leaf litter, Amandeep Kaur, PUN 4348, July 14, 2010. |
| 42. | *C. subxerophytica* var. *brunnea* Hauskn. | Barnala (228 m), Sherpur, growing in groups on horse dung, Amandeep Kaur, PUN 4217, July 13, 2008. |
| 43. | *C. subxerophytica* var. *subxerophytica* Singer & Hauskn. | Patiala (251m), Samana, growing scattered on buffalo dung, Amandeep Kaur, PUN 4216, June 25, 2008. |
| 44. | *C. uralensis* Hauskn., Knudsen & Mukhin | Ropar (394 m): Kuraali, growing in groups on buffalo dung heap, Amandeep Kaur, PUN 4218, August 21, 2009. |
| 45. | *C. velutipes* (Velen.) Hauskn. & Svrček | Moga (217 m): Ajitwal, growing scattered on cow dung, Amandeep Kaur, PUN 4803, August 13, 2010. |
| **III.** | **Entolomataceae** Kotlába & Pouzar | |
| **ix.** | ***Rhodocybe*** Maire | |

| Sr. No. | Taxa | Ecology & Distribution |
|---|---|---|
| 46. | *R. popinalis* var. *macrosporus* Amandeep Kaur, NS Atri & Munruchi Kaur | Hoshiarpur (295 m), Asalpur, growing in caespitose groups on mixed cattle and horse dung heap, Amandeep Kaur, PUN 4804, July 14, 2010. |
| **IV.** | **Lyophyllaceae** Jülich | |
| **x.** | ***Termitomyces*** R. Heim | |
| 47. | *T. radicatus* Natarajan | Sangrur (231 m), Dohla, growing gregariously on cattle manured soil along road side, Amandeep Kaur, PUN 4805, August 19, 2010; Ferozepur (182 m), Badaduraka, growing gregariously in caespitose groups on mixed cattle dung among grasses, Amandeep Kaur, PUN 4806, August 16, 2011. |
| **V.** | **Pluteaceae** Kotl. & Pouzar | |
| **xi.** | ***Volvariella*** Speg. | |
| 48. | *V. hypopithys* (Fr.) Shaffer | Sangrur (231 m), Langrian, growing scattered on buffalo dung, Amandeep Kaur, PUN 4215, June 21, 2008. |
| 49. | *V. pusilla* (Pers.) Singer | Sangrur (231 m), Jamalpura, growing in caespitose cluters on mixed cattle and camel dung heap, Amandeep Kaur, PUN 4807, June 22, 2008. |
| **xii.** | ***Volvopluteus*** Vizzini, Contu & Justo | |
| 50. | *V. earlei* (Murrill) Vizzini, Contu and Justo | Patiala (251 m), Lahore Majra, growing scattered in groups on buffalo dung, Amandeep Kaur, PUN 4808, June 23, 2008; Patiala (251 m): Bhavanigarh Road, growing scattered in groups on buffalo dung, Amandeep Kaur, PUN 4809, June 23, 2008. |
| 51. | *V. gloiocephalus* (DC.: Fr.) Vizzini, Contu & Justo | Sangrur (231 m), Bhavanigarh, growing in groups on mixed cattle dung, Amandeep Kaur, PUN 4810, June 23, 2008; Hoshiarpur (295 m), Siprian, growing scattered on mixed horse and cattle dung, Amandeep Kaur, PUN 4811, July 14, 2010; Sangrur (231 m), Madevi, growing in a caespitose group on buffalo dung, Amandeep Kaur, PUN 4812, June 27, 2011. |
| **VI.** | **Psathyrellaceae** Vilgalys, Moncalvo & Redhead | |
| **xiii.** | ***Coprinellus*** P. Karst. | |
| 52. | *C. ephemerus* (Bull.) Redhead, Vilgalys & Moncalvo | Hoshiarpur (295 m), Mehlanwaali, growing in groups on mixed cattle dung, Amandeep Kaur, PUN 4813, July 05, 2011. |
| 53. | *C. micaceus* (Bull.: Fr.) Vilgalys, Hopple & Jacq. Johnson | Patiala (251 m), Bhunerheri, growing in groups on mixed dung, Amandeep Kaur, PUN 4814, June 16, 2008; Hoshiarpur (295 m), Tanda, growing in groups on humicolous, manured soil, Narinderjit Kaur, PUN 4684, July 23, 2011. |
| 54. | *C. truncorum* (Scopoli) Redhead, Vilgalys & Moncalvo | Ludhiana (254 m), Kamaalpura, growing in groups on mixed cattle dung, Amandeep Kaur, PUN 4815, January 30, 2010. |
| **xiv.** | ***Coprinopsis*** P. Karst. | |
| 55. | *C. cinerea* (Schaeff.) Redhead, Vilgalys & Moncalvo | Sangrur (231 m): Sikanderpura, growing in groups on mixed cattle dung, Amandeep Kaur, PUN 4816, June 02, 2008; Patiala (251 m): Kalyan, growing in groups on horse dung, Amandeep Kaur, PUN 4817, January 31, 2010. |
| 56. | *C. cothurnata* var. *equsterca* Atri, A. Kaur & M. Kaur | Barnala (228 m), Salempur, growing in a caespitose group on horse dung, Amandeep Kaur, PUN 4064, February 08, 2009. |
| 57. | *C. foetidella* (P. D. Orton) Atri, A. Kaur & M. Kaur | Moga (217 m), Jallalabad, growing in group on buffalo dung, Amandeep Kaur, PUN 4818, June 28, 2011. |
| 58. | *C. lagopides* var. *lagopides* (P. Karst.) Redhead, Vilgalys & Moncalvo | Sangrur (231 m), Naushehra, scattered on mixed cattle dung and straw heap, Amandeep Kaur, PUN 4060, July 09, 2007. |

| Sr. No. | Taxa | Ecology & Distribution |
|---|---|---|
| 59. | *C. lagopus* (Fr.) Redhead, Vilgalys & Moncalvo | Sangrur (231 m), Amargarh, growing in groups on mixed cattle dung, Amandeep Kaur, PUN 4819, June 21, 2008. |
| 60. | *C. macrocephala* (Berk.) Redhead, Vilgalys & Moncalvo | Jalandhar (233 m), Rahimpur, growing scattered on mixed cattle dung and straw residue heap, Amandeep Kaur, PUN 4820, July 30, 2010. |
| 61. | *C. nivea* (Pers.) Redhead, Vilgalys & Moncalvo | Sangrur (231 m), Amargarh, growing in groups on buffalo dung, Amandeep Kaur, PUN 4821, June 21, 2008; Mahorana, growing in caespitose groups on buffalo dung, Amandeep Kaur, PUN 4822, June 21, 2008; Sangrur (231 m), Takhar, growing gregariously on buffalo dung, Amandeep Kaur, PUN 4823, June 26, 2008; Ludhiana (254 m), Nasrali, growing in groups on horse dung, Amandeep Kaur, PUN 4824, July 23, 2009; Sangrur (231 m), Chittanwala, growing in groups on buffalo dung flakes, Amandeep Kaur, PUN 4825, July 25, 2010. |
| 62. | *C. pseudonivea* (Bender & Uljé) Redhead, Vilgalys & Moncalvo | Punjab: Sangrur (231 m), Langrian, growing in groups on cow dung, Amandeep Kaur, PUN 4062, June 21, 2008; Sangrur (231 m): Khurd, growing in groups on mixed cattle dung, Amandeep Kaur, PUN 4826, July 05, 2008; Tarn Taran (169 m): Kang, Khadoor Sahib, growing in a group of two on cow dung, Amandeep Kaur, PUN 4063, December 12, 2009. |
| 63. | *C. radiata* (Bolton: Fr.) Redhead, Vilgalys & Moncalvo | Patiala (251 m), Near Bhadson, Babulpur, growing on cattle dung, Amanjeet Kaur, PUN 2955, September 08, 1998; Patiala (251 m), Bhedpura, growing in a caespitose group on mixed cattle dung heap, Amandeep Kaur, PUN 4827, July 16, 2011. |
| 64. | *C. radiata* var. *macrocarpa* Atri, A. Kaur & M. Kaur | Sangrur (231 m), Bhasaur, growing in groups on buffalo dung, Amandeep Kaur, PUN 4828, September 15, 2007; Sangrur (231 m), Langrian, growing in groups on mixed cattle dung, Amandeep Kaur, PUN 4829, June 21, 2008; Patiala (251 m), Chhat Bir, growing in groups on mixed cattle dung heap, Amandeep Kaur, PUN 4830, June 30, 2008; Sangrur (231 m), Sandaur, growing scattered on mixed cattle dung, Amandeep Kaur, PUN 4831, September 29, 2008. |
| 65. | *C. scobicola* (P.D. Orton) Redhead, Vilgalys & Moncalvo | Sangrur (231 m), Meemsa, growing solitary on sheep dung, Amandeep Kaur, PUN 4832, July 25, 2010. |
| 66. | *C. vermiculifera* (Joss.: Dennis) Redhead, Vilgalys & Moncalvo | Hoshiarpur (295 m), Garhshankar, growing in a group on buffalo dung, Amandeep Kaur, PUN 4833, July 05, 2011. |
| **xv.** | ***Panaeolus*** (Fr.) Quél. | |
| 67. | *P. acuminatus* (Schaeff.) Quél. | Bathinda (211 m), Lehra Mohabbat, growing gregariously in cattle pasture, Amandeep Kaur, PUN 4030, August 02, 2009. |
| 68. | *P. africanus* var. *diversistipus* Amandeep Kaur, NS Atri & Munruchi Kaur | Hoshiarpur (295 m), Jejon Duaba, growing solitary on mixed cattle dung heap, Amandeep Kaur, PUN 4342, July 05, 2011. |
| 69. | *P. alcidis* Moser | Moga (217 m), Chak Fatehpur, growing scattered or in caespitose groups on buffalo dung, Amandeep Kaur, PUN 4359, June 28, 2011. |
| 70. | *P. antillarum* (Fr.) Dennis | Sangrur (231 m), Ratolan, growing solitary on mixed cattle dung, Amandeep Kaur, PUN 4225, September 28, 2008. |
| 71. | *P. ater* (J.E. Lange) Kühner & Romagn. | Fatehgarh Sahib (228 m), Nogwaan, growing scattered on cattle dung, Amandeep Kaur, PUN 4032, August 21, 2009; Hoshiarpur (295 m), Chak Sadhu, growing in groups on buffalo dung, Narinderjit Kaur, PUN 4704, July 22, 2011. |
| 72. | *P. castaneifolius* (Murrill) A.H. Sm. | Sangrur (231 m), Sikanderpura, growing in groups on mixed cattle dung, Amandeep Kaur, PUN 4358, June 29, 2011; Patiala (251 m), Ghanaur, growing solitary on buffalo dung, Amandeep Kaur, PUN 4357, July 19, 2011. |
| 73. | *P. cyanescens* (Berk. & Br.) Sacc. | Fatehgarh Sahib (228 m), Sirhind, along G.T. Road, growing in groups on mixed dung and humicolous soil under *Eucalyptus citridora* tree, Amanjeet Kaur, PUN 2708, September 16, 1995; Fatehgarh Sahib (228 m), Sirhind, growing in caespitose groups on cattle manure in the field of *Allium sativum* crop, Amanjeet Kaur, PUN 2712, November 17, 1995; Fatehgarh Sahib (228 m), Sirhind, growing |

| Sr. No. | Taxa | Ecology & Distribution |
|---|---|---|
| | | in groups on cattle dung, Amanjeet Kaur, PUN 2707, November 17, 1995; Fatehgarh Sahib (228 m), Sirhind, growing in groups on cattle manured soil, Amanjeet Kaur, PUN 2711, November 27, 1995; Patiala (250 m), Bir Bhunerheri, growing scattered on cattle manured soil near *Parthenium* grass, Amanjeet Kaur, PUN 2710, March 07, 1998; Fatehgarh Sahib (228 m), Bassi, growing scattered on mixed dung, Amanjeet Kaur, PUN 2713, September 14, 1998; Fatehgarh Sahib (228 m), Sirhind, growing in groups on cattle dung manured soil in *Allium sativum* field, Amanjeet Kaur, PUN 2709, November 28, 1998; Sangrur (251 m), Malak Majra, growing gregariously on buffalo dung, Amandeep Kaur, PUN 4355, June 23, 2008; Patiala (251 m), Dakala, Dashmesh Nagar, growing gregariously on cow dung, Amandeep Kaur, PUN 4077, June 25, 2008; Patiala (251 m), Chhat Bir, growing in caespitose clusters on buffalo dung, Amandeep Kaur, PUN 4028, June 30, 2008; Patiala (251 m), Chhat Bir, growing gregariously on buffalo dung, Amandeep Kaur, PUN 4078, June 30, 2008; Hoshiarpur (295 m), Simbli, growing scattered on mixed cattle dung, Harwinder Kaur, PUN 4361, July 19, 2008; Ludhiana (254 m), growing in groups on cattle dung, Baljit Kaur, PUN 3922, September 03, 2008; Ludhiana (254 m), Nasrali, growing scattered in groups on mixed cattle dung, Amandeep Kaur, PUN 4079, July 23, 2009; Mohali (31 6m), Bhajauli, growing scattered on cow dung heap, Amandeep Kaur, PUN 4031, August 21, 2009; Ropar (394 m), Kuraali, growing solitary on mixed cattle dung, Amandeep Kaur, PUN 4033, August 21, 2009; Sangrur (251 m): Jaatimajra, growing gregariously on horse dung, Amandeep Kaur, PUN 4080, September 03, 2009; Patiala (251 m), Chhat Bir, growing in groups on elephant dung, Amandeep Kaur, PUN 4353, July 10, 2010; Patiala (251 m), Chhat Bir, growing scattered on elephant dung, Amandeep Kaur, PUN 4354, July 10, 2010; Ropar (394 m), near Haveli, growing in groups on buffalo dung, Arpana Lamba, PUN 4296, July 16, 2010; Ropar (394 m), growing in groups on buffalo dung, Arpana Lamba, PUN 4297, July 25, 2010. |
| 74. | *P. cyanoannulatus* Atri, M. Kaur & A. Kaur | Hoshiarpur (295 m), Jeewanpur Jattan, found growing in a group on a mixed cow and horse dung heap in a pasture, Amandeep Kaur, PUN 4223, July 18, 2008. |
| 75. | *P. lepus-stercus* Atri, M. Kaur & A. Kaur | Pathankot (309 m), Sheep and Rabbit Breeding Farm Dalla Dhar, growing scattered on rabbit pellets, Amandeep Kaur, PUN 4340, September 01, 2011. |
| 76. | *P. papilionaceus* var. *parvisporus* Ew. Gerhardt | Sangrur (231 m), Dugni, growing in groups on buffalo dung among grasses along roadside, Amandeep Kaur, PUN 4360, June 27, 2011. |
| 77. | *P. solidipes* (Peck) Sacc. | Sangrur (231 m), Upoki, growing solitary on horse dung, Amandeep Kaur, PUN 4034, September 04, 2009. |
| 78. | *P. speciosus* var. *pilocystidiosus* Amandeep Kaur, NS Atri & Munruchi Kaur | Barnala (228m), Rarh, growing scattered on cattle dung, Amandeep Kaur, PUN 4081, June 26, 2008. |
| 79. | *P. sphinctrinus* (Fr.) Quél. | Hoshiarpur (295 m), Mahilpur, growing gregariously on horse dung in a pasture, Munruchi Kaur and Amandeep Kaur, PUN 4224, July 18, 2008; Bathinda (211 m), Lehra Mohabbat, growing gregariously in caespitose groups on cow dung, Amandeep Kaur and Harwinder Kaur, PUN 4029, August 02, 2009. |
| 80. | *P. subbalteatus* (Berk. & Br.) Sacc. | Barnala (228 m), Wazeedake, growing in groups on buffalo dung among grasses, Amandeep Kaur, PUN 4228, July 31, 2009; Bathinda (211m), Nandgarh, growing scattered on buffalo dung, Amandeep Kaur, PUN 4227, August 01, 2009; Ropar (394 m), Padiala, growing in groups on a mixed cattle dung heap, Amandeep Kaur, PUN 4229, August 21, 2009; Ropar (394 m): Kiratpur Sahib, growing in groups on mixed cattle dung, Harwinder Kaur, PUN 4770, July 13, 2012. |
| 81. | *P. tropicalis* Oláh | Patiala (251 m), Nainakut, growing in groups on mixed cattle dung, Amandeep Kaur, PUN 4076, June 16, 2008; Patiala (251 m), Bhunerheri, growing in groups on mixed cattle dung, Amandeep Kaur, PUN 4346, June 16, 2008; Hoshiarpur (295 m), Kot Fatuhi, growing solitary on mixed cattle dung among grassy litter, Narinderjit Kaur, PUN 4341, August 18, 2011. |
| 82. | *P. venezolanus* Guzmán | Faridkot (196 m), Panjgraean, growing in a group on cattle dung and wheat straw mixture heap, Amandeep Kaur, PUN 4834, August 19, 2011. |
| **xvi.** | ***Parasola*** Redhead, Vilgalys & | |

| Sr. No. | Taxa | Ecology & Distribution |
|---|---|---|
| | Hopple | |
| 83. | *P. plicatilis* (Curtis) Redhead, Vilgalys & Hopple | Kapurthala (224 m), growing scattered on manured soil, Jyoti Mann and Amandeep Kaur, PUN 4059, May 15, 2007. |
| **xvii.** | ***Psathyrella*** Fr.: Quél. | |
| 84. | *P. conopilea* (Fr.) Pearson & Dennis | Sangrur (231 m), Bhudan, growing solitary on buffalo dung and vegetable waste heap, Amandeep Kaur, PUN 4073, January 20, 2008. |
| 85. | *P. fimicola* NS Atri, Munruchi Kaur and Amandeep Kaur | Patiala (251m), Harigarh, growing in group on horse dung, Amandeep Kaur, PUN 4317, June 18, 2011. |
| 86. | *P. flocculosa* (Earle) A.H. Smith | Sangrur (231 m), Naushehra, growing gregariously on mixed cattle dung heap, Amandeep Kaur, PUN 4074, July 07, 2007. |
| 87. | *P. kauffmanii* var. *kauffmanii* Smith | Moga (217 m), Loahgarh, growing in caespitose clusters on buffalo dung heap under *Azadirachta indica* tree, Amandeep Kaur, PUN 4318, July 28, 2009. |
| 88. | *P. sphaerocystis* Orton | Sangrur (231 m), Balamgarh, growing in caespitose cluster on mixed cattle dung heap, Amandeep Kaur, PUN 4075, July 30, 2009. |
| 89. | *P. vanhermanii* Smith | Mohali (316 m), Parol, growing in groups on buffalo dung, Amandeep Kaur, PUN 4316, July 14, 2007; Ludhiana (254 m): Issru, growing in groups on buffalo dung, Amandeep Kaur, PUN 4315, June 17, 2008. |
| **VII.** | **Strophariaceae** Singer & Smith | |
| **xviii.** | ***Agrocybe*** Fayod | |
| 90. | *A. microspora* Singer | Patiala (251 m): Bahadurgarh, growing in groups on manured soil in a cattle pasture, Munruchi Kaur and Yadwinder Singh, PUN 4835, May 28, 2008. |
| 91. | *A. pediades* (Fr.) Fayod | Sangrur (231m): Kelon, growing in groups on mixed cattle dung, Amandeep Kaur, PUN 4226, August 14, 2008. |
| **xix.** | ***Protostropharia*** Redhead, Moncalvo & Vilgalys | |
| 92. | *P. semiglobata* var. *punjabensis* Amandeep Kaur, NS Atri and Munruchi Kaur | Punjab: Pathankot (309 m), Berkula, growing solitary on cow dung in an open pasture, Munruchi Kaur and Amandeep Kaur, PUN 4840, September 02, 2011. |
| **xx.** | ***Psilocybe*** (Fr.) P. Kumm. | |
| 93. | *P. aztecorum* var. *aztecorum* Heim emend. Guzmán | Patiala (251 m), Wazeedpur, growing solitary on buffalo dung, Amandeep Kaur, PUN 4837, July 16, 2011; Pathankot (309 m): Shahpur Kandi, growing in group on buffalo dung, Munruchi Kaur and Amandeep Kaur, PUN 4838, September 01, 2011. |
| 94. | *P. aztecorum* var. *bonetii* (Guzmán) Guzmán | Hoshiarpur, Badowan (295 m), growing scattered on a buffalo dung flake, Munruchi Kaur and Amandeep Kaur, PUN 4836, July 18, 2008. |
| 95. | *P. semilanceata* (Fr.) P. Kumm. | Patiala (251 m), Bhunerheri, growing in groups on mixed cattle dung heap in a pasture, Amandeep Kaur, PUN 4839, June 16, 2008. |

## Frequency of occurrence of different taxonomic categories

The extensive collection trips to dung localities in Punjab were undertaken during the years 2007-2011. A total of 172 coprophilous collections belonging to 95 taxa falling under 20 genera representing 07 agaric families have been taxonomically investigated.

It was observed that the coprophilous mushrooms belong to numerous unrelated taxa of different families **(Table 1).** However, 94.2% of the collections belonged to most of the dark-spored families namely, *Psathyrellaceae*, *Agaricaceae*, *Bolbitiaceae*, and *Strophariaceae* while only 5.8% collections were of light spored families namely *Pluteaceae*, *Lyophyllaceae*, and *Entolomataceae*. Thus in comparison the mushrooms belonging to light spored families were negligible **(Fig. 3).**

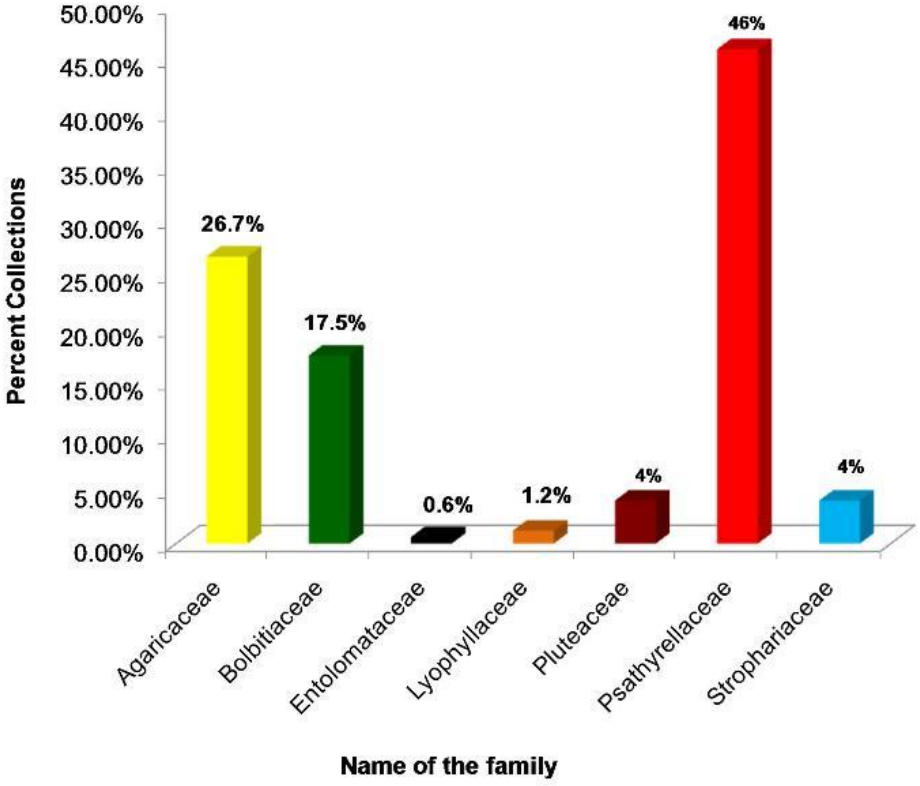


**Fig. 3** – Occurrence of investigated taxa in different families.

The collections belonging to *Psathyrellaceae* (46%) were the most frequent coprophilous mushrooms in Punjab plains. As compared, the members of *Agaricaceae* representing 26.7% of the total collections were also quite frequent in the dung localities followed by those of *Bolbitiaceae* (17.5%) and *Strophariaceae* (4%).

Amongst the light spored agarics, the members of family *Pluteaceae* were the most common in the coprophilous localities represented by 4% of the total collections. These were followed by the members of *Lyophyllaceae* (1.2%) and *Entolomataceae* (0.6%) **(Figs. 4 & 5).**

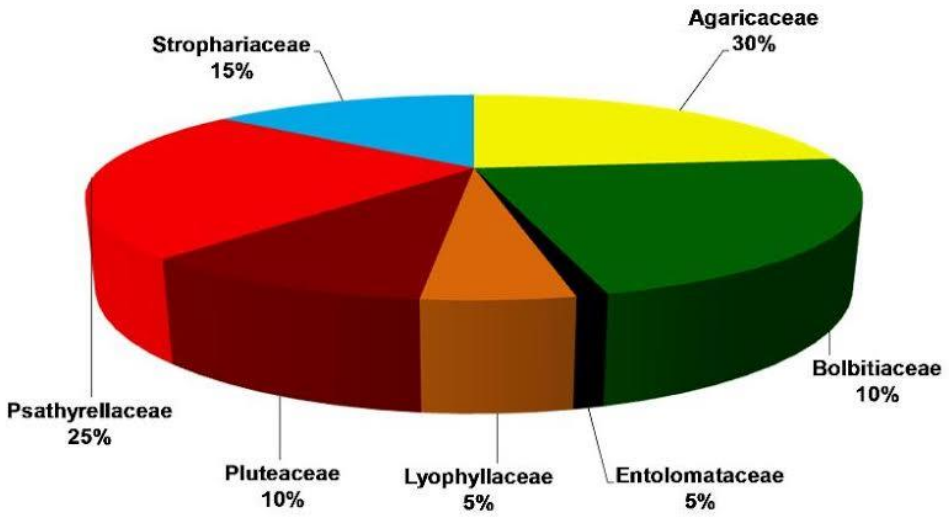


**Fig. 4** – Genus wise distribution in different families.

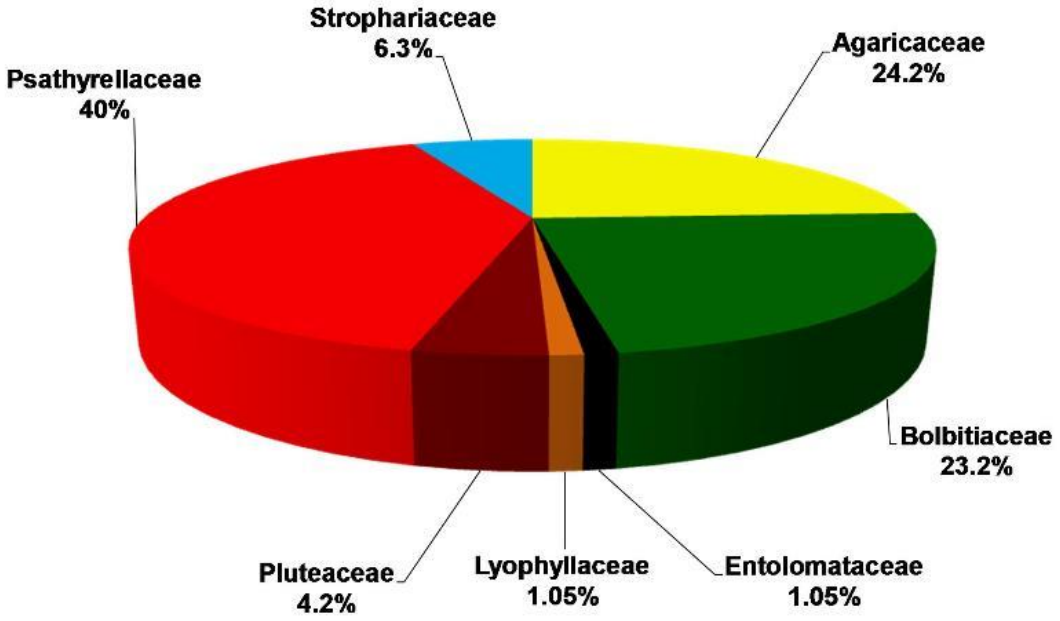


**Fig. 5** – Species wise distribution in different families.

It has been reported that the heavily pigmented spores as those of dark spored families protect themselves from ultraviolet light until they are consumed by herbivorous animals (Ingold 1971, Bell 1983). The spores of families *Psathyrellaceae*, *Agaricaceae*, *Bolbitiaceae*, and *Strophariaceae* are relatively large and heavily pigmented in comparison to those of families *Pluteaceae*, *Lyophyllaceae*, and *Entolomataceae*. Thus, the size of spores and pigmentation in them seems to contribute to the more frequent occurrence of mushrooms belonging to most of the dark spored families in comparison to light spored families. Amongst the dark spored taxa, the maximum frequency of members belonging to family *Psathyrellaceae* may be because the majority of its genera possess deliquescing gills. Probably the spores of such genera are efficiently scattered to distant places by insects feeding on these in comparison to non-deliquescent genera.

Amongst the light spored families, *Pluteaceae* show more frequent occurrence than *Lyophyllaceae* and *Entolomataceae*. The members of family *Pluteaceae* have gelatinous spores. The gelatinized material on the spore surface seems to help in the improved adhesion of the spores to the surrounding vegetation and thus there are more chances for these to be eaten by herbivorous animals. During present study the genera *Rhodocybe* and *Termitomyces* belonging to light spored families *Entolomataceae* and *Lyophyllaceae* respectively, otherwise non-coprophilous in their habitat, were also collected from dung. The species of *Rhodocybe* are mostly saprobic or ectomycorrhizal in broadleaved and coniferous forests and those of *Termitomyces* are usually associated with the termite nests (Singer 1986). But presently *Rhodocybe popinalis* var. *macrosporus* was collected from mixed dung habitat while *Termitomyces radicatus* was documented on manured soil besides mixed dung locality. Both these taxa seem to be opportunistic and not true coprophilous mushrooms, as their spores seem to have arrived from somewhere else. There can be possibility of dung being defecated at the locations with mycelia of these mushrooms entrapped underneath. Amongst the investigated taxa, *Bolbitius coprophilous, B. demangei, Conocybe apala, C. moseri, C. fuscimarginata, Coprinus sterquilinus, C. comatus, Chlorophyllum molybdites, Leucocoprinus cepistipes, Lepiota humei, Agaricus campestris, A. xanthodermus, A. halophilus, Psathyrella vanhermanii, Panaeolus castaneifolius, P. cyanescens, P. sphinctrinus, P. subbalteatus, P. tropicalis, Coprinopsis cinerea, C. radiata, C. nivea, C. pseudonivea, Coprinellus micaceus,* and *Volvariella gloiocephala* were very common in coprophilous habitats of Punjab and were encountered many times from 2007–2011.

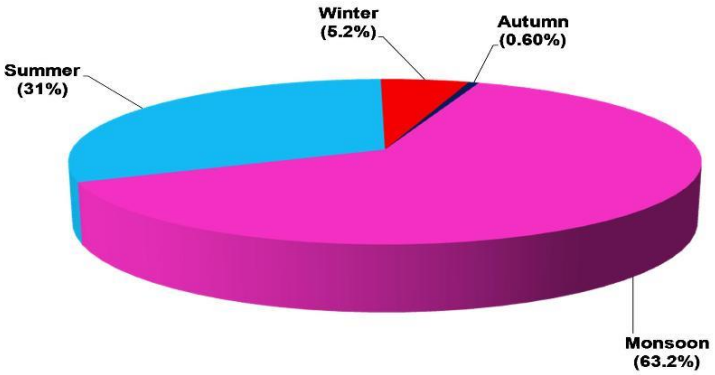


**Fig. 6** – Seasonal occurrence of investigated coprophilous taxa.

**Frequency of distribution in different seasons**

During present investigation, 63.2% of the total collections were found during monsoon season from July to September and 31% in summer season from May to June while 5.2% collections were made in winter season from November to February. Only small percentage (0.6%) was found in post winter autumn season **(Fig. 6)**.

On monthly basis, the number of coprophilous mushrooms collected was maximum in July (29%) which correspond to the beginning of monsoon season in Punjab. As many as 28.7% collections were made in the month of June when there are scattered rains here and there in the state. As compared, 21% of the total collections were made during August, 13.2% during September, 2.3% each during the months of May and November and 1.7% during January. However, during the months of February, March and December, the frequency of occurrence of these mushrooms was only 0.6% in each case which is almost negligible. No collection was found during the months of April and October **(Fig. 7).**

The season wise evaluation reveals that the coprophilous mushrooms belonging to as many as 18 genera were encountered during monsoon season, 15 genera during summer season, 04 genera in winter season and only 01 genus in autumn season **(Table 2).**

Amongst the various genera documented in monsoon season, the mushrooms belonging to *Panaeolus* (16.8% collections) were quite frequent, followed by *Conocybe* (10%), *Lepiota* (6.3%), *Coprinopsis* (6.3%), *Agaricus* (4.6%), *Leucocoprinus* (3.5%), *Bolbitius* (2.3%), *Coprinus* (2.3%), *Psathyrella* (2.3%), *Chlorophyllum* (1.7%), *Psilocybe* (1.7%), *Coprinellus* (1.2%), and *Termitomyces* (1.2%). In comparison the collections belonging to *Leucoagaricus*, *Agrocybe*, *Protostropharia*, *Rhodocybe* and *Volvopluteus* (0.6% in each case) were least frequent.

Out of the total 18 genera documented during monsoon season, the mushrooms belonging to 05 genera, namely *Leucoagaricus, Leucocoprinus, Protostropharia, Rhodocybe* and *Termitomyces* were collected during this season only. None of their species were present during summer, winter and autumn seasons, thereby emphasizing their preference for warmer and humid conditions in comparison to other genera which were quite frequent during summer months as well. In summer season also the collections of *Panaeolus* (5.8%) were more common in comparison to the percentage of collections of *Coprinopsis* (5.3%), *Lepiota* (3.5%), *Conocybe* (3%), *Bolbitius* (2.3%), *Volvopluteus* (2.3%), *Coprinus* (1.7%), *Agaricus* (1.7%), *Psathyrella* (1.2%), and *Volvariella* (1.2%). However, the collections belonging to *Chlorophyllum, Parasola, Coprinellus, Agrocybe* and *Psilocybe* (0.6% each) were least frequent. Out of these genera, coprophilous mushrooms belonging to *Parasola* and *Volvariella* were collected only during summer months showing their preference for warmer climatic conditions. In winter season as well, the collections of genus *Panaeolus* (2.3%) were more common in comparison to *Coprinopsis* (1.7%), *Psathyrella* (0.6%), and *Coprinellus* (0.6%). Although only few collections of these four genera were encountered during winter season, however, their occurrence during this season demonstrates their resistance to low temperature and chilly weather which is normally inclement for mushroom growth. During the present study, only one collection (0.6%) belonging to genus *Panaeolus*

was met with during autumn season. It has been observed that out of the total 20 investigated genera, the genus *Panaeolus* is distributed in all the seasons. The appearance of *Panaeolus* in all the seasons reflects high resistance of its mycelium in various climatic conditions to actively grow and gather enough resources so as to produce fruit bodies.

It has been observed that 04 genera, namely *Psathyrella*, *Panaeolus*, *Coprinopsis* and *Coprinellus*, were commonly distributed in monsoon, summer and winter seasons. A total of 09 genera viz. *Bolbitius*, *Conocybe*, *Coprinus*, *Chlorophyllum*, *Lepiota*, *Agaricus*, *Agrocybe*, *Psilocybe*, and *Volvopluteus* were encountered both in summer and monsoon seasons. This demonstrates their potential to adapt to varied climatic fluctuations in comparison to other coprophilous mushrooms **(Table 2).**

**Table 2** Genus wise frequency of occurrence in different seasons.

| **Season→ Genus ↓** | **Monsoon** | **Summer** | **Winter** | **Autumn** |
|---|---|---|---|---|
| ***Agaricus*** | 4.6% | 1.7% | —— | —— |
| ***Chlorophyllum*** | 1.7% | 0.6% | —— | —— |
| ***Coprinus*** | 2.3% | 1.7% | —— | —— |
| ***Lepiota*** | 6.3% | 3.5% | —— | —— |
| ***Leucoagaricus*** | 0.6% | —— | —— | —— |
| ***Leucocoprinus*** | 3.5% | —— | —— | —— |
| ***Bolbitius*** | 2.3% | 2.3% | —— | —— |
| ***Conocybe*** | 10% | 3% | —— | —— |
| ***Rhodocybe*** | 0.6% | —— | —— | —— |
| ***Termitomyces*** | 1.2% | —— | —— | —— |
| ***Volvariella*** | —— | 1.2% | —— | —— |
| ***Volvopluteus*** | 0.6% | 2.3% | —— | —— |
| ***Coprinellus*** | 1.2% | 0.6% | 0.6% | —— |
| ***Coprinopsis*** | 6.3% | 5.3% | 1.7% | —— |
| ***Panaeolus*** | 16.8% | 5.8% | 2.3% | 0.6% |
| ***Parasola*** | —— | 0.6% | —— | —— |
| ***Psathyrella*** | 2.3% | 1.2% | 0.6% | —— |
| ***Agrocybe*** | 0.6% | 0.6% | —— | —— |
| ***Protostropharia*** | 0.6% | —— | —— | —— |
| ***Psilocybe*** | 1.7% | 0.6% | —— | —— |
| **Total→** | **63.2%** | **31%** | **5.2%** | **0.6%** |

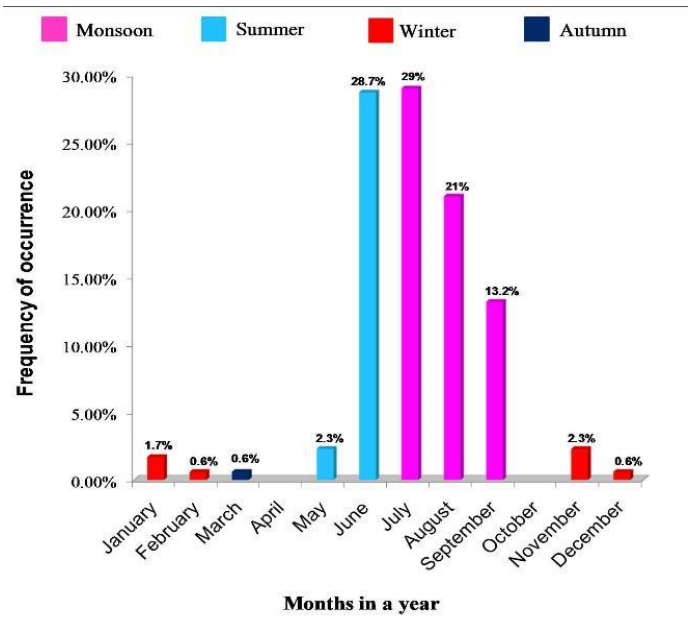


**Fig. 7** – Month wise per cent distribution of investigated coprophilous taxa.

Out of all 95 species identified, only 01 species (1.05%), namely *Panaeolus cyanescens* was documented in all the major seasons throughout the year while *Coprinopsis pseudonivea* (1.05%) in three seasons namely monsoon, summer and winter. As many as 15 species (15.7%) including *Bolbitius coprophilous, B. demangei*, *Conocybe apala*, *Coprinus sterquilinus*, *C. comatus* var. *caprimammillatus*, *Lepiota humei*, *Agaricus campestris*, *A. xanthodermus, Psathyrella vanhermanii, Panaeolus tropicalis, P. castaneifolius, Coprinopsis radiata* var. *macrocarpa, Coprinopsis nivea, Coprinellus micaceus,* and *Volvopluteus gloiocephala* were encountered in both summer and monsoon seasons and *Coprinopsis cinerea* (1.05%) was found in both summer and winter seasons.

The majority of mushrooms belonging to 55 species (58%) were available exclusively in monsoon season. These are *Bolbitius glatfelteri, B. titubans, Conocybe subxerophytica* var. *brunnea, C. leucopus, C. magnicapitata, C. subpubescens, C. uralensis, C. microrrhiza* var. *coprophila, C. moseri, C. velutipes, C. lenticulospora, C. rickenii, C. crispa, C. albipes, Coprinus comatus* var. *comatus*, *C. cordispora, Chlorophyllum molybdites, Leucoagaricus naucinus, Leucocoprinus cepistipes, L. straminellus, Lepiota thrombophora, L. epicharis* var. *occidentalis, L. thiersii, L. xanthophylla, L. subincarnata, Agaricus halophilus, A. placomyces, A. cupreobrunneus, A. flavistipus, A. stellatus-cuticus, Psathyrella kauffmanii* var. *kauffmanii, P. sphaerocystis, P. flocculosa, Panaeolus solidipes, P. antillarum, P. ater, P. africanus* var. *diversistipus, P. lepus-stercus, P. cyanoannulatus, P. venezolanus, P. subbalteatus, P. acuminatus, P. sphinctrinus, Coprinopsis vermiculifera, C. scobicola, C. lagopides* var. *lagopides, C. macrocephala, C. radiata, Coprinellus ephemerus, Agrocybe pediades, Protostropharia semiglobata* var. *punjabensis, Psilocybe aztecorum* var. *aztecorum, Psilocybe aztecorum* var. *bonetii, Rhodocybe popinalis* var. *macrosporus,* and *Termitomyces radicatus.* As many as 19 species (20%), namely *Bolbitius marginatipes, B. vitellinus, Conocybe brachypodii, C. subxerophytica* var. *subxerophytica, C. fuscimarginata, Chlorophyllum rhacodes*, *Agaricus pratensis*, *Psathyrella fimicola, Panaeolus alcis, P. papilionaceus* var. *parvisporus, P. speciosus* var. *pilocystidiosus, Parasola plicatilis, Coprinopsis lagopus, C. foetidella, Agrocybe microspora, Psilocybe semilanceata, Volvariella hypopithys, V. pusilla* and *Volvopluteus earlei,* were collected during summer season.

Presently, 03 taxa (3.15%) namely *Psathyrella conopilea*, *Coprinopsis cothurnata* var. *equsterca* and *Coprinellus truncorum* were recorded growing exclusively in winter season **(Fig. 8).**

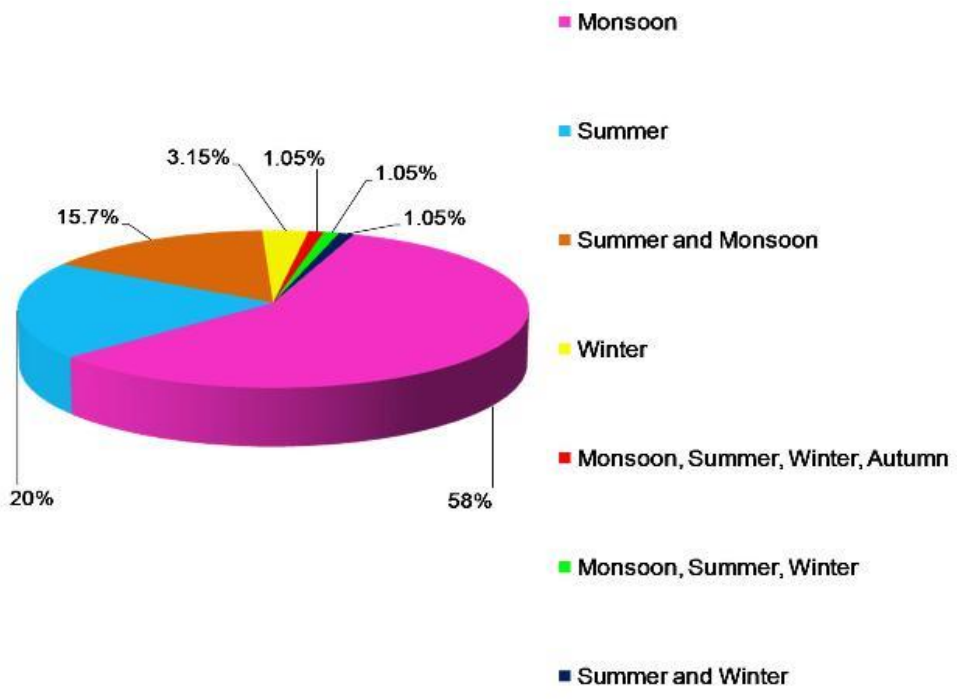


**Fig. 8** – Species wise distribution of investigated taxa in different seasons.

It has been reported that the best condition for the occurrence of mushrooms is the moderate temperature and high moisture in the environment and the substrate (Pacioni 1985). In Punjab, these climatic conditions are available in monsoon season with 70-80% of the total rainfall taking place during this season (Manku 2002). The less intense heat, moist air alongwith high moisture contents of the dung during this period (from July to September) favors the mushroom growth. The fungal mycelium collects water and dissolved minerals from the dung substrates efficiently during monsoons. Thus the rainy season characterizes the peak season for coprophilous mushroom growth in the present study area. That is why majority of these mushrooms (63.2%) were collected during monsoon season. As compared, the summer season (from May to June) is very hot in the state. The highest day time temperature rises up to 47°C during the months of May and June (Manku 2002). Due to high temperature and dry air, dung loses moisture and free oxygen and thus the rate of mushroom growth slows down during summer. Sometimes there is a pre-monsoon rainfall which favors the mushroom growth in this period. It is because of this pre-monsoon rain that 31% of coprophilous mushrooms were collected during summer months despite extremely unfavorable climate. In winter season (November to February), the winds are cold and dry in Punjab. Brief showers and low to moderate temperature seems to have contributed to the occasional occurrence of coprophilous mushrooms during this season. In Punjab, the months of March–April and October represent the post winter and post monsoon autumn season, respectively. Frost and fog are common from mid January to mid February which probably retarded mushroom growth in the month of March. The transitional seasons have alternating wet and dry spell and fluctuating climatic conditions in Punjab (Manku 2002). Thus no mushroom was collected during the months of April and October.

**Frequency of distribution in different regions**

The different dung localities in the central, north-east and south-west regions of Punjab explored during the present investigation are analyzed for richness and diversity of coprophilous mushrooms. It is apparent from the data generated that 60% of the total coprophilous collections were distributed in the central region representing districts Sangrur, Patiala, Ludhiana, Moga, Jalandhar and Kapurthala. These mushrooms were less frequently distributed in north-east region representing districts Hoshiarpur, Ropar, Fatehgarh Sahib, Mohali, and Pathankot as it is evident from the occurrence of 25.5% of the total collections in this region. As compared, only 14.5% of the total collections were made from south-west region representing Barnala, Faridkot, Bathinda, Ferozepur and Tarn Taran districts during the years 2007–2011 **(Fig. 9).**

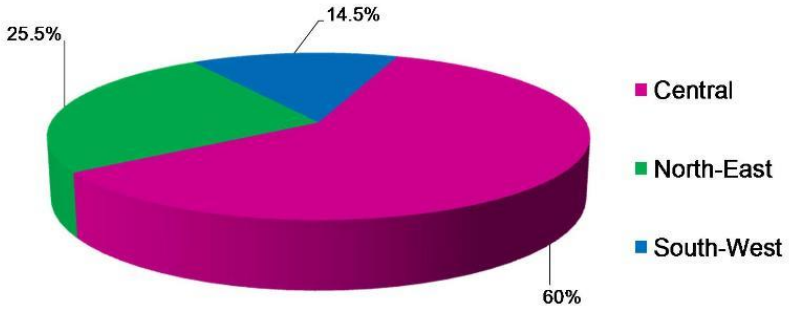


**Fig. 9** – Occurrence of investigated taxa in different regions.

As for district wise distribution is concerned, 28% collections were encountered growing from district Sangrur, 20.3% from Patiala, 12.2% from Hoshiarpur, 5.3% each from Ludhiana and Ropar, 4.6% from Moga, 4% from Fatehgarh Sahib, 3.5% each from Barnala and Faridkot, 2.9% each from Ferozepur and Bathinda, 2.3% from Mohali, 1.7% each from Pathankot and Tarn Taran, 1.2% from Jalandhar and 0.6% from Kapurthala **(Fig. 10).**

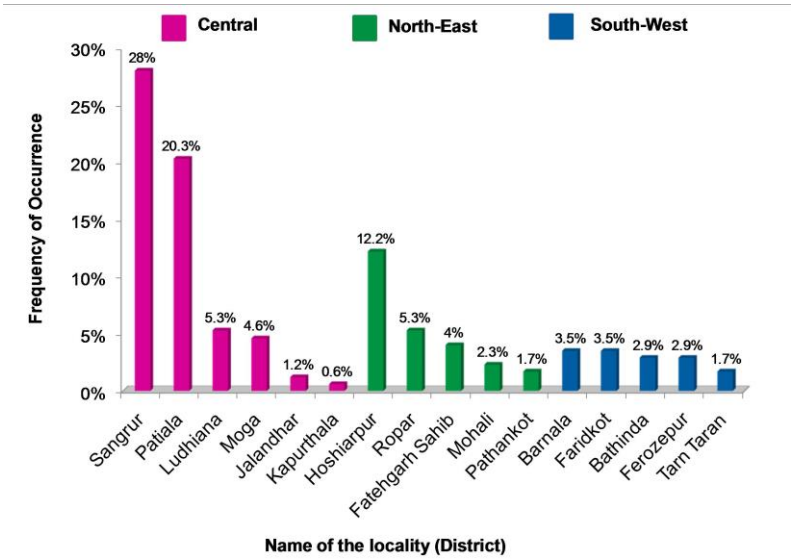


**Fig. 10** – District wise distribution of coprophilous mushrooms.

Out of the total 20 investigated genera, 17 genera were encountered from the central region, 15 genera from the north-east region and 08 genera from the south-west region. The mushrooms belonging to 6 genera, namely *Conocybe*, *Coprinus*, *Lepiota*, *Agaricus*, *Panaeolus* and *Coprinopsis* were quite frequent in all regions of the state while those belonging to *Chlorophyllum*, *Leucocoprinus*, *Psathyrella*, *Coprinellus*, *Psilocybe*, and *Volvopluteus* were quite common in both central and north-east regions. The genera *Bolbitius* and *Termitomyces* have been documented from both central and south-west regions. The coprophilous collections belonging to as many as 03 genera, namely *Parasola*, *Agrocybe*, *Volvariella*, were found distributed only in the central region while 03 genera namely *Leucoagaricus*, *Protostropharia* and *Rhodocybe* were found growing exclusively in the north-east region of Punjab **(Table 3).**

**Table 3** – Genus wise frequency of occurrence in different regions.

| **Region→ Genus ↓** | **Central** | **North-East** | **South-West** |
|---|---|---|---|
| ***Agaricus*** | 4.6% | 0.6% | 1.2% |
| ***Chlorophyllum*** | 1.2% | 1.2% | —— |
| ***Coprinus*** | 2.3% | 0.6% | 1.2% |
| ***Lepiota*** | 6.4% | 1.7% | 1.7% |
| ***Leucoagaricus*** | —— | 0.6% | —— |
| ***Leucocoprinus*** | 1.2% | 2.3% | —— |
| ***Bolbitius*** | 4.1% | —— | 0.6% |
| ***Conocybe*** | 6.4% | 1.7% | 4.6% |
| ***Rhodocybe*** | —— | 0.6% | —— |
| ***Termitomyces*** | 0.6% | —— | 0.6% |
| ***Volvariella*** | 1.2% | —— | —— |
| ***Volvopluteus*** | 2.3% | 0.6% | —— |
| ***Coprinellus*** | 1.2% | 1.2% | —— |
| ***Coprinopsis*** | 11.4% | 0.6% | 1.2% |
| ***Panaeolus*** | 10.5% | 11.4% | 3.4% |
| ***Parasola*** | 0.6% | —— | —— |
| ***Psathyrella*** | 3.6% | 0.6% | —— |
| ***Agrocybe*** | 1.2% | —— | —— |
| ***Protostropharia*** | —— | 0.6% | —— |
| ***Psilocybe*** | 1.2% | 1.2% | —— |
| **Total→** | **60%** | **25.5%** | **14.5%** |

In central region, the frequency of distribution of *Coprinopsis* (11.4%) was maximum, followed by *Panaeolus* (10.5%), *Conocybe* (6.4%), *Lepiota* (6.4%), *Agaricus* (4.6%), *Bolbitius* (4.1%), *Psathyrella* (3.6%), *Coprinus* (2.3%), and *Volvopluteus* (2.3%). As compared, the genera *Chlorophyllum, Leucocoprinus, Coprinellus, Agrocybe, Psilocybe,* and *Volvariella* representing 1.2% collections in each case were less frequently distributed. The distribution of mushrooms belonging to *Parasola* (0.6%) and *Termitomyces* (0.6%) was the lowest in central region. In north-east region, the frequency of distribution for *Panaeolus* (11.4%) was maximum, as compared to *Leucocoprinus* (2.3%), *Conocybe* (1.7%), *Lepiota* (1.7%), *Chlorophyllum* (1.2%), *Coprinellus* (1.2%), and *Psilocybe* (1.2%). The genera *Coprinus, Leucoagaricus, Agaricus, Psathyrella, Coprinopsis, Protostropharia, Rhodocybe* and *Volvopluteus* were represented by only 0.6% collections in each case from this region. In south-west region, the frequency of distribution for *Conocybe* (4.6%) was maximum, followed by *Panaeolus* (3.4%), *Lepiota* (1.7%), *Coprinus* (1.2%), *Agaricus* (1.2%) and *Coprinopsis* (1.2%). As compared, the collections belonging to *Bolbitius* (0.6%) and *Termitomyces* (0.6%) were less frequent in this region **(Table 3)**.

Out of 95 mushroom species investigated, *Conocybe apala* was the only species documented from all the three geographical regions of the study area. As many as 09 taxa, (9.5%) namely *Chlorophyllum molybdites, Leucocoprinus cepistipes, Agaricus halophilus, Psathyrella vanhermanii, Panaeolus tropicalis, P. cyanescens, Coprinellus micaceus, Psilocybe aztecorum* var. *bonetii,* and *Volvopluteus gloiocephala* were collected from the coprophilous habitats of both the central and the north-east regions of Punjab while 08 species (8.5%), namely *Bolbitius demangei, Conocybe fuscimarginata, Coprinus sterquilinus, C. comatus* var. *caprimammillatus, Lepiota humei, Agaricus campestris, Coprinopsis pseudonivea,* and *Termitomyces radicatus* were recorded from both the central and south-west regions. Two taxa namely *Panaeolus subbalteatus* and *Panaeolus sphinctrinus* were well spread both in north-east and south-west regions **(Fig. 11).**

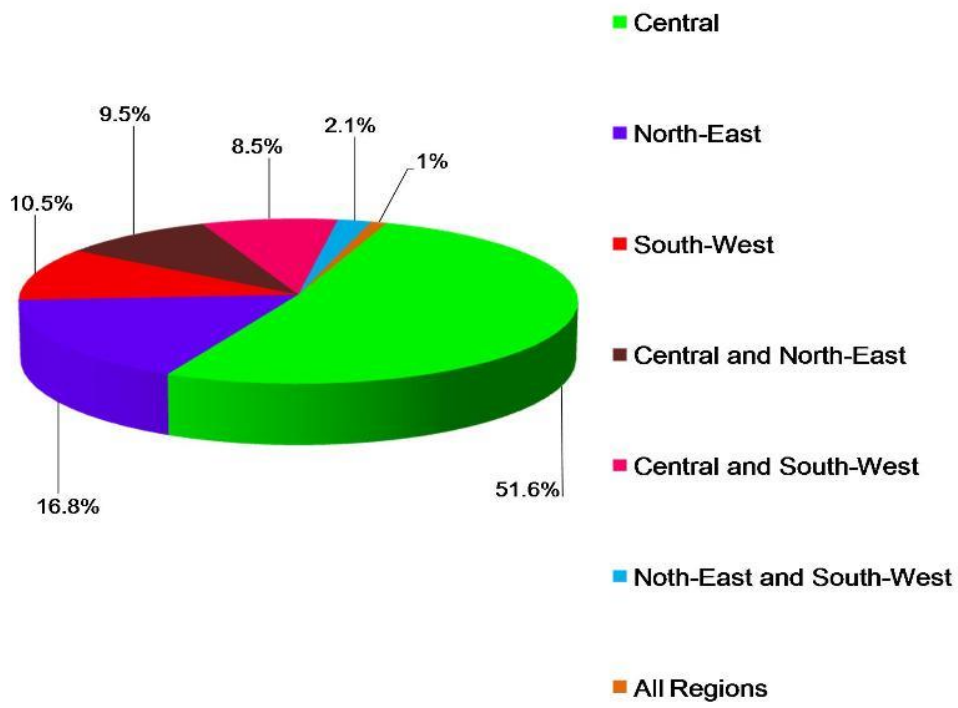


**Fig. 11** – Species wise distribution of coprophilous taxa in different regions.

From the central region 49 species (51.6%) of diverse coprophilous mushrooms have been collected and identified. These are *Bolbitius glatfelteri, B. marginatipes, B. titubans, B. vitellinus, B. coprophilous, Conocybe brachypodii, C. subxerophytica* var. *subxerophytica, C. moseri, C. velutipes, C. lenticulospora, C. rickenii, C. crispa, C. albipes, Coprinus comatus* var. *comatus, Chlorophyllum*

*rhacodes, Leucocoprinus straminellus, Lepiota subincarnata, Agaricus pratensis, A. placomyces, A. xanthodermus, A. cupreobrunneus, A. stellatus-cuticus, Psathyrella kauffmanii var. kauffmanii, P. fimicola, P. sphaerocystis, P. conopilea, P. flocculosa, Panaeolus solidipes, P. antillarum, P. castaneifolius, P. alcis, P. papilionaceus* var. *parvisporus, Parasola plicatilis, Coprinopsis scobicola, C. lagopus, C. lagopides* var. *lagopides, C. macrocephala, C. cinerea, C. radiata, C. radiata* var. *macrocarpa, C. foetidella, C. nivea, Coprinellus truncorum, Agrocybe microspora, A. pediades, Psilocybe semilanceata, Volvariella hypopithys, V. pusilla,* and *Volvopluteus earlei*. As many as 16 taxa (16.8%) were exclusively collected from the north-east region. These are *Conocybe subpubescens, C. uralensis, Coprinus cordispora, Leucoagaricus naucinus, Lepiota thrombophora, Lepiota epicharis* var. *occidentalis, Lepiota thiersii, Panaeolus ater, P. africanus* var. *diversistipus, P. lepus-stercus, P. cyanoannulatus, Coprinopsis vermiculifera, Coprinellus ephemerus, Protostropharia semiglobata* var. *punjabensis, Psilocybe aztecorum* var. *aztecorum,* and *Rhodocybe popinalis* var. *macrosporus.* During the present study 10 taxa (10.5%), namely *Conocybe subxerophytica* var. *brunnea, C. leucopus, C. magnicapitata, C. microrrhiza* var. *coprophila, Lepiota xanthophylla, Agaricus flavistipus, Panaeolus venezolanus, P. acuminatus, P. speciosus* var. *pilocystidiosus,* and *Coprinopsis cothurnata* var. *equsterca* have been found growing only in the south-west region of the state **(Fig. 11).**

It has been reported that the distribution of coprophilous fungi is influenced by the climatic conditions, the environmental gradients, the type of vegetation, and the kind of herbivorous dung (Webster 1970, Angel & Wicklow 1975, Piontelli *et al.* 2006, Kumar *et al.* 1995). The central region of Punjab, comprising Sangrur, Patiala, Ludhiana, Jalandhar, Moga, and Kapurthala districts, is the main agricultural region of the state having semi-arid climate, moderate rainfall, abundance of animal population and altitude more than 200 meters above the sea level (Manku 2002). Due to fertile loamy to clayey soil, flat land, and more irrigation facilities available from tubewells and canals, intensive agriculture is practiced in the central region of the state. Buffaloes and cattle are the major components of farm animals in this region. Sheep and camels are also domesticated in some parts of Sangrur and Patiala districts. All these factors might have contributed to the maximum distribution of coprophilous mushrooms in the central region. The difference in the number of taxa between the different regions could be due to the difference in the number of samples studied from a particular region. During present investigation, the maximum collection trips were undertaken in the central region as the permanent laboratory is situated at Patiala. This is also the major factor responsible for maximum collections from this region. Richardson (2001) reported the increase in the number of mushrooms recorded with an increase in the number of samples studied.

In North-east region of Punjab covering sub-humid foothill areas of Pathankot, Hoshiarpur, Ropar, and Mohali, the soil texture is loamy to clayey (Manku 2002). The region receives moderate to high rainfall. The amount of rainfall increases north-eastwards. This region has sufficient vegetation cover and livestock population. Ample collections belonging to diverse coprophilous mushrooms have been made from this region. The South-West region, comprising Bathinda, Barnala, Faridkot, Ferozepur and Tarn Taran districts, has very hot and arid climate and the soil in this region is dry and calcareous which is reported to lack nitrogen and potash (Manku 2002). The amount of rainfall decreases and the aridity increases south-westward. The region is near to the Rajasthan desert having little vegetation cover and mostly sheep, goats, camels, and donkeys are domesticated, hence, fewer coprophilous mushrooms were encountered in this region.

**Frequency of distribution on different dung types**

The coprophilous mushrooms were found growing on dung of various domesticated and wild herbivorous animals in pastures, open areas, zoological parks, and on mixed dung heaps along roadsides or along village ponds, etc. in different regions of Punjab. During present investigation, 44.8% of the total collections were found growing on mixed dung heaps, as compared to those on buffalo dung (33%), cow dung (5.8%), manured soil (5.8%), horse dung (5.2%), elephant dung (1.8%), camel dung (1.2%) and sheep dung (1.2%). The frequency of distribution from rabbit and deer dung was very low (0.6% each) in the present study **(Fig. 12, Table 4).**

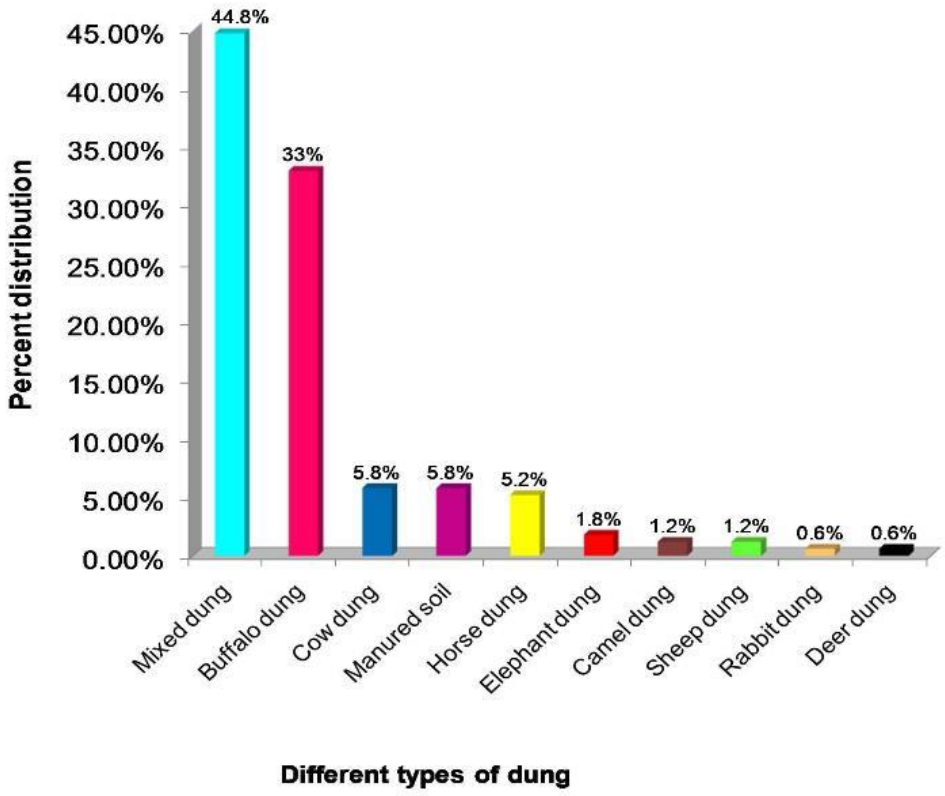


**Fig. 12** – Frequency of occurrence of investigated mushrooms on different dung types.

**Table 4** Genus wise frequency of occurrence on different dung types.

| Dung type→ Genus ↓ | Mixed | Buffalo | Manured soil | Cow | Horse | Elephant | Camel | Sheep | Rabbit | Deer |
|---|---|---|---|---|---|---|---|---|---|---|
| ***Agaricus*** | 3.5% | 1.7% | —— | —— | —— | —— | —— | 0.6% | —— | 0.6% |
| ***Chlorophyllum*** | 0.6% | 1.2% | —— | —— | —— | —— | 0.6% | —— | —— | —— |
| ***Coprinus*** | 3% | —— | 0.6% | —— | 0.6% | —— | —— | —— | —— | —— |
| ***Lepiota*** | 5.2% | 3% | 1.2% | —— | —— | —— | 0.6% | —— | —— | —— |
| ***Leucoagaricus*** | 0.6% | —— | —— | —— | —— | —— | —— | —— | —— | —— |
| ***Leucocoprinus*** | 2.3% | 1.2% | —— | —— | —— | —— | —— | —— | —— | —— |
| ***Bolbitius*** | 0.6% | 4% | —— | —— | —— | —— | —— | —— | —— | —— |
| ***Conocybe*** | 4.1% | 5.2% | —— | 2.3% | 0.6% | 0.6% | —— | —— | —— | —— |
| ***Rhodocybe*** | 0.6% | —— | —— | —— | —— | —— | —— | —— | —— | —— |
| ***Termitomyces*** | 0.6% | —— | 0.6% | —— | —— | —— | —— | —— | —— | —— |
| ***Volvariella*** | 0.6% | 0.6% | —— | —— | —— | —— | —— | —— | —— | —— |
| ***Volvopluteus*** | 1.2% | 1.7% | —— | —— | —— | —— | —— | —— | —— | —— |
| ***Coprinellus*** | 1.7% | —— | 0.6% | —— | —— | —— | —— | —— | —— | —— |
| ***Coprinopsis*** | 5.8% | 4% | —— | 1.2% | 1.7% | —— | —— | 0.6% | —— | —— |
| ***Panaeolus*** | 12% | 6.4% | 1.6% | 1.7% | 1.7% | 1.2% | —— | —— | 0.6% | —— |
| ***Parasola*** | —— | —— | 0.6% | —— | —— | —— | —— | —— | —— | —— |
| ***Psathyrella*** | 1.2% | 2.3% | —— | —— | 0.6% | —— | —— | —— | —— | —— |
| ***Agrocybe*** | 0.6% | —— | 0.6% | —— | —— | —— | —— | —— | —— | —— |
| ***Protostropharia*** | —— | —— | —— | 0.6% | —— | —— | —— | —— | —— | —— |
| ***Psilocybe*** | 0.6% | 1.7% | —— | —— | —— | —— | —— | —— | —— | —— |
| **Total→** | **44.8%** | **33%** | **5.8%** | **5.8%** | **5.2%** | **1.8%** | **1.2%** | **1.2%** | **0.6%** | **0.6%** |

Out of 20 mushroom genera investigated from the study area, 18 genera were encountered from mixed dung, 12 genera from buffalo dung, 07 genera from manured soil, 05 genera from horse dung, 04 genera from cow dung, 02 genera from elephant dung, 02 genera from camel dung, 02 genera from sheep dung and 01 genus each from rabbit dung and deer dung **(Table 4).**

The members of the genus *Panaeolus* have shown the maximum diversity regarding their growth on different type of herbivorous dung. They were found growing on seven different types of

dung substrates including mixed, buffalo, cow, horse, elephant, and rabbit and also on manured soil. The species belonging to the genus *Coprinopsis* were found growing on mixed, buffalo, cow, horse, and sheep dung types. The genus *Conocybe* was also found growing on five diverse dung types including mixed, buffalo, cow, horse, and elephant dung. The members of *Agaricus* have been collected from four dung types namely mixed, buffalo, sheep and deer dung and those of *Lepiota* from mixed, buffalo, camel dung and manured soil. The genus *Coprinus* was observed growing on mixed dung, horse dung and manured soil, *Chlorophyllum* on mixed, buffalo and camel dung, and *Psathyrella* on mixed, buffalo, and horse dung types. The taxa belonging to the genera *Bolbitius, Leucocoprinus, Psilocybe, Volvariella* and *Volvopluteus* were confined to two dung types, viz. mixed and buffalo dung. The genera *Coprinellus, Agrocybe*, and *Termitomyces* were found growing on mixed dung and manured soil. The other investigated genera *Leucoagaricus* and *Rhodocybe* were found on mixed dung, *Parasola* on manured soil and *Protostropharia* on cow dung **(Table 4).**

Among the mushrooms growing on mixed dung, the members of the genus *Panaeolus* (12%) have been observed to have maximum frequency followed by those of *Coprinopsis* (5.8%), *Lepiota* (5.2), *Conocybe* (4.1%), *Agaricus* (3.5%), *Coprinus* (3%), *Leucocoprinus* (2.3%), *Coprinellus* (1.7%), and *Psathyrella* and *Volvopluteus* (1.2% each). The frequency of occurrence of *Bolbitius, Chlorophyllum, Leucoagaricus, Agrocybe, Psilocybe, Rhodocybe, Volvariella*, and *Termitomyces* (0.6% each) on mixed dung heaps is very low as is evident from **Table 4.**

On buffalo dung, the genus *Panaeolus* (6.4%) was more frequent in comparison to other genera including *Conocybe* (5.2%), *Coprinopsis* (4%), *Bolbitius* (4%), *Lepiota* (3%), *Psathyrella* (2.3%), and *Agaricus, Psilocybe*, and *Volvopluteus* (1.7% each). The frequency of occurrence of *Chlorophyllum* (1.2%) and *Leucocoprinus* (1.2%) was very low in comparison. The genus *Volvariella* (0.6%) was least frequent. During present study no member belonging to genera *Coprinus, Leucoagaricus, Parasola, Coprinellus, Agrocybe, Protostropharia, Rhodocybe*, and *Termitomyces* were collected from buffalo dung. Some members of *Panaeolus* (1.6%), *Lepiota* (1.2%), and *Coprinus, Parasola, Coprinellus, Agrocybe*, and *Termitomyces* (0.6% each) were also collected from the manured soil. From the horse dung only 05 genera, namely *Panaeolus, Coprinopsis, Conocybe, Coprinus* and *Psathyrella* were collected. Amongst the documented genera, *Panaeolus* and *Coprinopsis* (1.7% each) were comparatively more frequent than *Conocybe, Coprinus* and *Psathyrella* (0.6% each).

On cow dung, the members of *Conocybe* (2.3%) were found growing more frequently than those of *Panaeolus* (1.7%), and *Coprinopsis* (1.2%). Only one species of *Protostropharia* (0.6%) was collected during the present investigation from cow dung. From elephant dung, only the taxa belonging to *Panaeolus* (1.2%) and *Conocybe* (0.6%) were collected.

The frequency of occurrence of mushrooms on camel and sheep dung was very low in comparison to other dung of herbivorous animals. Only few collections belonging to genus *Chlorophyllum* (0.6%) and *Lepiota* (0.6%) were made from the camel dung. Similarly from sheep dung occasional collections of *Agaricus* (0.6%) and *Coprinopsis* (0.6%) were made. Only one collection of *Panaeolus lepus-stercus* was documented growing on rabbit dung from Sheep and Rabbit Breeding Farm, Dalla-Dhar in district Pathankot. Similarly only one collection of *Agaricus placomyces* was made from the dung of deer from M. C. Zoological Park, Chhat Bir (**Table 4).**

Of all the 95 taxa identified, *Panaeolus cyanescens* was collected from diverse dung types. It was collected from mixed, buffalo, cow, horse, elephant dung, and manured soil. Presently, *Coprinus sterquilinus* was collected from mixed, horse dung and manured soil, *Chlorophyllum molybdites* from mixed, buffalo, and camel dung, and *Lepiota humei* from mixed dung, buffalo dung and dung manured soil. As many as 10 coprophilous mushrooms were found growing both on mixed dung and buffalo dung. These are *Bolbitius demangei, Conocybe apala, Leucocoprinus cepistipes, Agaricus campestris, A. halophilus, Panaeolus ater, P. castaneifolius, P. subbalteatus, Coprinopsis radiata* var. *macrocarpa, Volvopluteus gloiocephala*. Two taxa, namely *Conocybe fuscimarginata* and *Coprinopsis pseudonivea*, were collected from mixed dung and cow dung and two taxa, namely *Coprinellus micaceus* and *Termitomyces radicatus* from mixed dung and manured soil. *Coprinopsis cinerea* was collected both from mixed and horse dung, *Coprinopsis nivea* from buffalo dung and horse dung and *Panaeolus sphinctrinus* from cow dung and horse dung. As many as 31 taxa were found growing exclusively on

mixed dung heaps. These are *Conocybe brachypodii, C. subpubescens, C. moseri, C. lenticulospora, Coprinus comatus* var. *comatus, C. comatus* var. *caprimammillatus, C. cordispora, Leucoagaricus naucinus, Lepiota thrombophora, Agaricus pratensis, A. xanthodermus, A. cupreobrunneus, Psathyrella sphaerocystis, P. flocculosa, Panaeolus antillarum, P. tropicalis, P. africanus* var. *diversistipus, P. cyanoannulatus, P. venezolanus, P. acuminatus, P. speciosus* var. *pilocystidiosus, Coprinopsis lagopus, C. lagopides* var. *lagopides, C. macrocephala, C. radiata, Coprinellus ephemerus, Coprinellus truncorum, Agrocybe pediades, Psilocybe semilanceata, Rhodocybe popinalis* var. *macrosporus,* and *Volvariella pusilla.*

A total of 27 taxa, namely *Bolbitius glatfelteri, B. marginatipes, B. titubans, B. vitellinus, B. coprophilous, Conocybe subxerophytica* var. *subxerophytica, C. magnicapitata, C. uralensis, C. rickenii, C. crispa, Chlorophyllum rhacodes, Leucocoprinus straminellus, Lepiota epicharis* var. *occidentalis, L. thiersii, L. xanthophylla, Agaricus flavistipus, Psathyrella kauffmanii* var. *kauffmanii, P. vanhermanii, Psathyrella conopilea, Panaeolus alcis, P. papilionaceus* var. *parvisporus, Coprinopsis vermiculifera, Coprinopsis foetidella, Psilocybe aztecorum* var. *aztecorum, P. aztecorum* var. *bonetii, Volvariella hypopithys,* and *Volvopluteus earlei* were found associated only with buffalo dung. During present study 04 taxa, namely *Conocybe subxerophytica* var. *brunnea, Psathyrella fimicola, Panaeolus solidipes,* and *Coprinopsis cothurnata* var. *equsterca* were found growing exclusively on horse dung and another 04 taxa, namely *Conocybe leucopus, C. microrrhiza* var. *coprophila, C. velutipes,* and *Protostropharia semiglobata* var. *punjabensis* were documented growing exclusively on cow dung. As many as 02 taxa, namely *Agaricus stellatus-cuticus* and *Coprinopsis scobicola* were collected from sheep dung and 02 taxa, namely *Parasola plicatilis* and *Agrocybe microspora* exclusively from manured soil.

*Panaeolus lepus-stercus* was collected from rabbit dung, *Agaricus placomyces* from deer dung, *Conocybe albipes* from elephant dung and *Lepiota subincarnata* from camel dung.

Based upon the observations made, maximum number of mushrooms was found growing on mixed dung heaps, buffalo dung and cow dung followed by manured soil and horse dung. The frequency of occurrence of these mushrooms on elephant, camel and sheep dung was quite low in comparison. Mushrooms on rabbit and deer dung types were least distributed. The herbage feeding animals like buffaloes, cows, etc. are reported to have efficient digestive systems and these animals defecate fine-textured dung containing fibrous organic and inorganic components. Horses, with less efficient digestive system, produce much coarser dung which contains grass remains and weed seeds (Ing 1989, Richardson 1998, 2003). The consistency and composition of dung formed as a result of chewing and mastication in cattle during the process of digestion is reported to be highly suitable for mushroom growth (Morrison 1959, Lodha 1974). This could be the possible reason for occurrence of fewer mushrooms on coarse dung of horses in comparison to those appearing on the dung of ruminants. This study has shown that only 4% of the total investigated mushrooms were found in association with elephant, camel and sheep dung. The fewer number of mushrooms encountered with these substrates may be due to the fact that these animals might not be swallowing many coprophilous spores during grazing/feeding. Punjab, being an agrarian state, has more population of farm animals. Elephant dung deposits are not common in the state as this animal is not domesticated here. Elephants do come to Punjab from southern parts of India during festive season (from October to December) when prevalence of low temperature and lesser humidity do not favor mushroom growth on their deposits. Many of the presently investigated taxa belonging to the genera like *Panaeolus, Bolbitius, Conocybe, Psilocybe* and *Protostropharia* are known to occur on elephant dung in South India (Natarajan & Raaman 1983, 1984, Thomas *et al.* 2001, Thomas & Manimohan 2002, Manimohan *et al.* 2007). The least frequency of mushroom growth on rabbit and deer dung is probably attributed to the size and amount of moisture in their pellets which being small in quantity and almost dry and compact in consistency, cannot provide sufficient surface area and hydrature to support sufficient mushroom growth.

Presently no mushroom was found growing on goat dung which is otherwise rich in organic matter. This is also probably because very small sized compact pellets of goat lack sufficient amount of moisture in them to support mushroom growth.

**Frequency of distribution of agarics in different growing habits**

On the basis of their growing habit, the investigated taxa have been categorized as solitary, scattered or growing in small groups, gregarious, growing in caespitose clusters and fairy rings. Of all the 172 collections worked out, 67.4% were found growing scattered or in small groups followed by 14% mushrooms growing solitary, 8.6% growing gregariously, and 8.2% growing in caespitose clusters. Only 1.8% collections were observed forming fairy rings **(Fig. 13).**

Out of all the 20 investigated genera, 16 genera have been found growing scattered or in small groups, 10 genera growing solitary, 08 genera growing gregariously, 09 growing in caespitose clusters, and only 03 genera forming fairy rings **(Table 5).** The members of genera *Leucocoprinus, Parasola, Coprinellus,* and *Agrocybe* were noted growing only scattered on varied dung types. Taxa belonging to *Psilocybe* were found growing both solitary and scattered, and those belonging to *Termitomyces* were growing both gregariously and in caespitose clusters. The species of *Volvariella,* and *Volvopluteus* were noted growing both scattered and in caespitose clusters. The genera *Bolbitius, Coprinus* and *Lepiota* were observed growing solitary, scattered or in small groups, and also gregariously.

Taxa belonging to *Conocybe* were solitary, scattered, and also in caespitose clusters and those of *Chlorophyllum* were growing scattered to gregariously and formed fairy rings. During present study three genera, namely *Psathyrella, Panaeolus,* and *Coprinopsis* were found growing in diverse growing habits varying from solitary, scattered, gregarious to caespitose groups. The coprophilous species of *Agaricus* were found growing solitary, scattered, in caespitose clusters, and some of them also form fairy rings **(Table 5).**

**Table 5** – Genus wise frequency of occurrence in different growing habits.

| **Growing habit→ Genus ↓** | **Scattered or small groups** | **Solitary** | **Gregarious** | **Caespitose** | **Fairy rings** |
|---|---|---|---|---|---|
| ***Agaricus*** | 3.4% | 1.7% | —— | 0.6% | 0.6% |
| ***Chlorophyllum*** | 1.2% | —— | 0.6% | —— | 0.6% |
| ***Coprinus*** | 2.3% | 1.2% | 0.6% | —— | —— |
| ***Lepiota*** | 7% | 1.7% | 1.2% | —— | —— |
| ***Leucoagaricus*** | —— | —— | —— | —— | 0.6% |
| ***Leucocoprinus*** | 3.4% | —— | —— | —— | —— |
| ***Bolbitius*** | 3% | 1.2% | 0.6% | —— | —— |
| ***Conocybe*** | 10% | 2.4% | —— | 0.6% | —— |
| ***Rhodocybe*** | —— | —— | —— | 0.6% | —— |
| ***Termitomyces*** | —— | —— | 0.6% | 0.6% | —— |
| ***Volvariella*** | 0.6% | —— | —— | 0.6% | —— |
| ***Volvopluteus*** | 2.3% | —— | —— | 0.6% | —— |
| ***Coprinellus*** | 2.3% | —— | —— | —— | —— |
| ***Coprinopsis*** | 10.5% | 0.6% | 0.6% | 1.7% | —— |
| ***Panaeolus*** | 16.2% | 3.4% | 3.8% | 1.7% | —— |
| ***Parasola*** | 0.6% | —— | —— | —— | —— |
| ***Psathyrella*** | 1.7% | 0.6% | 0.6% | 1.2% | —— |
| ***Agrocybe*** | 1.2% | —— | —— | —— | —— |
| ***Protostropharia*** | —— | 0.6% | —— | —— | —— |
| ***Psilocybe*** | 1.7% | 0.6% | —— | —— | —— |
| **Total→** | **67.4%** | **14%** | **8.6%** | **8.2%** | **1.8 %** |

During the present investigation, *Panaeolus cyanescens* has shown the maximum diversity in its growing habit. It was noted growing solitary, scattered, gregariously, and also in caespitose clusters. *Lepiota humei* was growing solitary, scattered and even gregariously and *Coprinopsis nivea* was observed growing scattered, gregariously, and in caespitose groups. Five species, namely *Conocybe apala, Coprinus sterquilinus, Panaeolus tropicalis, Panaeolus castaneifolius* and *Psilocybe aztecorum* var. *bonetii* were observed growing solitary to scattered. Three species, namely *Bolbitius coprophilous, C. comatus* var. *caprimammillatus* and *Chlorophyllum molybdites* were collected growing both scattered and gregariously and another three species, viz. *Agaricus campestris, Coprinopsis radiata,* and *Volvopluteus gloiocephala* appeared scattered and in caespitose clusters. *Termitomyces radicatus* was found growing gregariously and in caespitose manner.

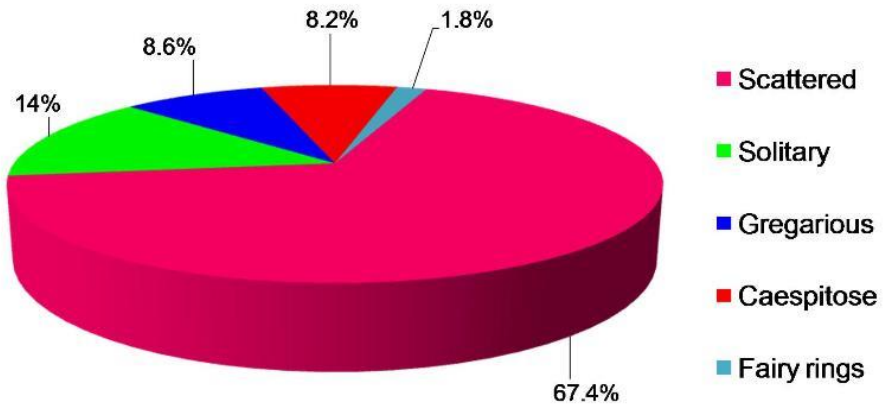


**Fig. 13** – Occurrence of investigated taxa in different growing habits.

As many as 52 taxa were noted growing either scattered or in small groups. These are *Bolbitius glatfelteri, B. marginatipes, B. demangei, Conocybe brachypodii, C. subxerophytica* var. *subxerophytica, C. subxerophytica* var. *brunnea, C. leucopus, C. subpubescens, C. uralensis, C. moseri, C. velutipes, C. lenticulospora, C. fuscimarginata, C. albipes, Coprinus comatus* var. *comatus, C. cordispora, Leucocoprinus cepistipes, Leucocoprinus straminellus, Lepiota thrombophora, Lepiota epicharis* var. *occidentalis, Lepiota thiersii, Lepiota xanthophylla, Agaricus halophilus, A. pratensis, A. xanthodermus, Psathyrella vanhermanii, Psathyrella fimicola, Panaeolus ater, P. lepus-stercus, P. cyanoannulatus, P. venezolanus, P. subbalteatus, P. papilionaceus* var. *parvisporus, P. speciosus* var. *pilocystidiosus, Parasola plicatilis, Coprinopsis vermiculifera, C. lagopus, C. lagopides* var. *lagopides, C. macrocephala, C. cinerea, C. radiata* var. *macrocarpa, C. foetidella, Coprinopsis pseudonivea, Coprinellus ephemerus, C. micaceus, C. truncorum, Agrocybe microspora, A. pediades, Psilocybe semilanceata, P. aztecorum* var. *aztecorum, Volvariella hypopithys,* and *Volvopluteus earlei.*

As many as 15 taxa were solitary in habit. These include *Bolbitius titubans, B. vitellinus, Conocybe magnicapitata, C. microrrhiza* var. *coprophila, C. rickenii, Lepiota subincarnata, Agaricus placomyces, A. flavistipus, A. stellatus-cuticus, Psathyrella conopilea, Panaeolus solidipes, P. antillarum, P. africanus* var. *diversistipus, Coprinopsis scobicola,* and *Protostropharia semiglobata* var. *punjabensis.*

Three taxa, namely *Psathyrella flocculosa, Panaeolus acuminatus, P. sphinctrinus,* were documented growing in gregarious manner. Seven taxa, namely *Conocybe crispa, Psathyrella kauffmanii* var. *kauffmanii, Psathyrella sphaerocystis, Panaeolus alcis, Coprinopsis cothurnata* var. *equsterca, Rhodocybe popinalis* var. *macrospores* and *Volvariella pusilla,* were found growing in caespitose clusters. Out of the total species examined, three taxa viz. *Chlorophyllum rhacodes, Leucoagaricus naucinus* and *Agaricus cupreobrunneus* were found forming fairy rings. It is quite apparent that the coprophilous mushrooms have the maximum tendency to grow scattered or in small groups followed by solitary growing habit. They have shown fewer tendencies to grow gregariously or in caespitose clusters and least tendency to grow in fairy rings. It has been reported that the moisture content of dung fluctuate very frequently and this influence the spread of mycelium into dung pellets and thus the extent of mushroom growth and type of growing habit on dung (Dickinson & Underhay 1977). The amount of dung substrates available is normally inadequate for centrifugal growth of fungal mycelium essential for the formation of fairy rings. The species of *Agaricus, Leucoagaricus* and *Chlorophyllum* are known to form fairy rings (Smith 1949, Dickinson & Lucas 1979). Presently, this has been confirmed but in the case of only three species namely *Agaricus cupreobrunneus, Leucoagaricus naucinus,* and *Chlorophyllum rhacodes.* These species were found forming fairy rings on old dung heaps.

Thus the coprophilous mushrooms have shown wide distribution and diversity amongst different taxa, seasons, regions, dung type and growing habits. During present study, they are represented by 95 taxa, and 20 genera belonging to 07 families growing solitary, scattered, gregariously or in fairy rings on a wide variety of herbivorous dung. They were found growing in monsoon, summer, winter, and autumn seasons in the central, north-east to south-west regions of Punjab.

**Economic utility of coprophilous mushrooms**

Out of the 95 coprophilous taxa investigated during the present study, 16% of the taxa have high edibility potential, 13.5% of the recorded taxa are reported to possess hallucinogenic or psychoactive properties, 6.3% taxa are reported to be poisonous, 5.2% taxa possess medicinal properties and culinary status of the rest 59% taxa is not available **(Fig. 14).** The information about their economic potential is based on the literature and no personal observations were made in this regard.

**Species with edibility potential**

Some of the wild coprophilous mushrooms, namely *Coprinus sterquilinus, C. comatus* var. *comatus, C. comatus* var. *caprimammillatus, Chlorophyllum rhacodes, Leucoagaricus naucinus, Agaricus campestris, A. placomyces, A. cupreobrunneus, A. halophilus, Panaeolus solidipes, P. acuminatus, Coprinellus micaceus, Protostropharia semiglobata* var. *punjabensis, Volvopluteus gloiocephala,* and *Termitomyces radicatus* were recorded growing in different dung localities of Punjab. Based upon the information available in the literature, all these are considered excellent from culinary point of view. However there is hardly any report of their consumption in Punjab.

*Coprinus sterquilinus* is a good edible mushroom. Many workers including Atkinson (1961) and Purkayastha & Chandra (1985) have documented it in their respective treatise. Kauffman (1918) reported this species growing in old manure or in manured ground from Michigan and documented its better flavor than any other *Coprinus* species. It is reported to be eaten by the local tribes in Kenya (Pegler 1977). *Coprinus comatus* is a commonly hunted mushroom for human consumption (Bose & Bose 1940, Atkinson 1961, Purkayastha & Chandra 1985, Singer 1986, Atri *et al.* 2007). Arora (1986) described it one of the safest and the best known edible species out of all the wild mushrooms which has delicate flavor and marvelous texture. It is reported to find ready market and serve as a source of revenue for the low income groups. It is being sold by the vegetable vendors during rainy reason in Patiala and Hoshiarpur districts of Punjab (Atri *et al.* 2007, 2009b). Presently it was found growing in scattered to gregarious clusters on mixed cattle dung from Moga, Sangrur and Bathinda districts of Punjab. Some of the presently recorded taxa like *Chlorophyllum rhacodes, Leucoagaricus naucinus, Agaricus campestris, A. placomyces, A. cupreobrunneus, A. halophilus,* and *Panaeolus solidipes* are reported to possess excellent edibility potential (Murrill 1922, Purkayastha & Chandra 1985, Arora 1986).

*Panaeolus acuminatus* is another edible species documented from Punjab which is reported to be quite popular in Scandinavia and Northern Europe (Stamets 1996). It has been listed to make a good strawberry milkshake (Singer 1986). During present study, it was documented growing gregariously on mixed cattle dung from Bathinda in south-west region of Punjab.

*Coprinellus micaceus* is another economically important species which was collected growing in groups on manured soil and mixed dung heaps. It has been reported as edible and having a good flavor (Kauffman 1918, Kaul & Kachroo 1974, Purkayastha & Chandra 1985). According to Wikipedia (http://en.wikipedia.org/wiki/*Coprinellus_micaceus*), it is considered ideal for omelettes, and as a flavor for sauces. *Protostropharia semiglobata* var. *punjabensis* was collected growing solitary on cow dung from Pathankot. According to Arora (1986), this is an edible species that grows solitary or in small groups on dung, manure rich soil, straw, and grazed or fertilized grass.

*Volvopluteus gloiocephala* was found growing scattered or in caespitose groups commonly on mixed dung and buffalo dung and it is reported to be an edible species by Justo *et al.* (2010a,b).

During the present investigation, one species of the genus *Termitomyces, T. radicatus* was collected growing gregariously on manured soil from Sangrur and in caespitose clusters on mixed dung

from Ferozepur. Although this mushroom is common in termitophilous habitats, its occurrence from coprophilous habitats is quite interesting (**Fig. 15**). This species possesses excellent edibility potential. It has been acclaimed as superior in taste to every other edible mushroom (Pegler & Piearce 1980). It is commonly consumed alongwith other termitophilous mushrooms in India (Natarajan 1977, Atri *et al.* 2005a). From the available information it is clear that some of the available wild coprophilous species especially *Coprinus comatus, Coprinus sterquilinus, Coprinellus micaceus, Chlorophyllum rhacodes* and *Agaricus campestris* possess enough potential for introduction into cultivation. This aspect offers scope for further investigations.

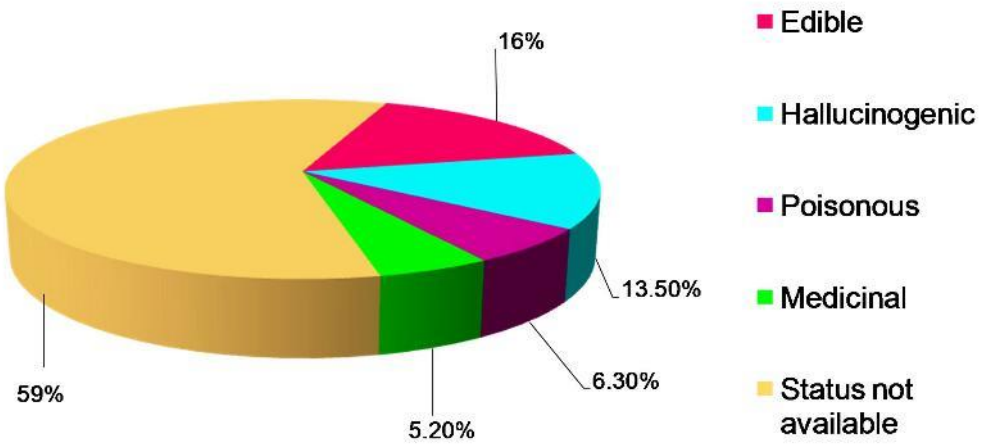


**Fig. 14** – Percent distribution of coprophilous taxa on the basis of their economic utility.

**Fig. 15** – *Termitomyces radicatus* growing on dung

**Inedible and poisonous species**

Many of the recorded coprophilous taxa including *Chlorophyllum molybdites, Leucocoprinus cepistipes, Lepiota xanthophylla, L. subincarnata, Agaricus xanthodermus,* and *Conocybe albipes* are not worth consideration for human consumption. They are reported to be inedible and poisonous in literature (Singer 1986, Arora 1986, Kerrigan 1986, Hall 2003, Vellinga 2001, 2003, Hallen *et al.* 2003). *Chlorophyllum molybdites* with large size and abundant carpophores was found growing on

camel dung, buffalo dung and mixed dung heaps during the rainy season from Sangrur, Hoshiarpur and Ropar districts in Punjab. It is considered a good edible mushroom in South America (Singer 1986), however, Arora (1986) listed it amongst the poisonous species of USA. People are reported to eat this mushroom, confusing it with shaggy mane (*Coprinus comatus*). It is reported to cause gastro-intestinal problems, especially when eaten raw (Arora 1986). 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). However, in Punjab, it is not consumed at all.

*Leucocoprinus cepistipes* is a wide spread species of very common occurrence in Punjab. It has been collected growing scattered on mixed cattle dung heap from Ropar and Hoshiarpur districts and growing on buffalo dung from Jalandhar district. This species is also reported to have adverse effects on health (Arora 1986).

*Lepiota xanthophylla* was recorded growing scattered on buffalo dung in the month of August from Faridkot district. Vellinga (2001) has reported this species as toxic. *Lepiota subincarnata* was collected growing solitary on camel dung in the month of September from Sangrur district. It 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). *Agaricus xanthodermus* is another mushroom which was collected from mixed cattle dung in the months of June and September from Sangrur district. It has been recorded to be a toxic species in literature which causes gastro-intestinal upsets (Kerrigan 1986). However, no information is available from Punjab in this regard. During the present study, *Conocybe albipes* was found growing scattered on elephant dung in the month of September from zoological park in Chhat Bir. According to Hallen *et al.* (2003), this species possesses the phallotoxins which accounts for its toxic effects.

**Species with medicinal properties**

Many of the investigated coprophilous mushrooms are important for their prospective utilization in human medicine and general health maintenance. Some of the inky caps, namely *Coprinus comatus*, *Coprinopsis radiata*, *C. lagopus* and *Coprinellus micaceus* are commonly recorded from Punjab. These are reported to possess antibiotic properties against bacteria and fungi (Botton & Siehr 1975, Ohtsuka *et al.* 1973, Efremenkova *et al.* 2001, 2003). *Coprinus comatus* has also been reported to have antidiabetic, antifungal and antibacterial properties (Efremenkova *et al.* 2001, 2003). Anisova *et al.* (1987) isolated four substances from *Coprinopsis radiata* which are reported to have antimicrobial and anticancer action. Zahid *et al.* (2006) reported in *Coprinellus micaceus* a unique chemical sterol 'Micaceol' with potential for use in cancer chemotherapy. *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 (Didukh *et al.* 2004), besides possessing antitumor and antiviral components (Chang & Hayes 1978).

*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 of Punjab which are reported to possess bioactive compounds (Didukh *et al.* 2004) with scope for utilization in human welfare.

**Hallucinogenic species**

The most famous hallucinogenic mushrooms belong to *Psilocybe* and *Panaeolus.* Most species of both these genera are reported to be dung-inhabiting (Stamets 1996, Allen & Gartz 1997, Guzmán *et al.* 2000, Guzmán and Trappe 2005). All the three presently documented taxa of the genus *Psilocybe*, viz. *P. semilanceata, P. aztecorum* var. *aztecorum,* and *P. aztecorum* var. *bonetii* are known to have hallucinogenic properties (Guzmán 1978; Stamets 1996). Some hallucinogenic species of *Panaeolus,* namely *P. africanus, P. acuminatus, P. antillarum, P. ater, P. castaneifolius, P. cyanescens, P. papilionaceus* var. *parvisporus, P. sphinctrinus, P. subbalteatus,* and *P. tropicalis* are reported to grow throughout the world on dung and well manured grounds (Stamets 1996, Allen & Gartz 1997). Presently all these species have been documented growing directly on different types of herbivorous

dung. Most of these species exhibit intense bluing reaction which occurs through oxidation of alkaloids after bruising and with age. But there is no available information about their consumption or collection as hallucinogens in the state.

**Habitat management to conserve coprophilous agarics**

Dung is an important substrate which serves as a favorable niche for the growth of a variety of fungi including mushrooms. These fungi play a significant role in the decomposition of organic matter, nutrient dynamics and maintenance of ecological balance on the earth. But the natural habitats with dung deposits such as pastures, grasslands, open fields, etc. are getting destroyed because of the various developmental activities. As most of the animals these days feed on improved, small pastures and are given food supplements, anti-helminthic drugs, antibiotics, etc., their droppings become unsuitable for the fungal growth (Webster 1999). The use of veterinary drugs and food supplements for rearing the domestic animals probably eliminates some dung fungi. As a result some of the coprophilous taxa are in danger of getting extinct (Webster 1999).

Coprophilous mushrooms are often delicate and short–lived. Any loss to their habitats will directly impact their diversity and result in their decline (Atri & Lakhanpal 2002). There is a need to check over exploitation of mushrooms. This can be done by enforcement of regulations available under CITES (Convention on International Trade in Endangered Species of Wild Fauna and Flora). There is a need to enforce ―The Wild Mushroom Pickers Code of Conduct (1998) which suggests that per visit no more than 1.5 kg of fungi should be collected, not more than half the fruiting bodies of any one species should be collected, only fully expanded mushrooms should be taken in order to permit some shedding of spores from the mature carpophores, and rare species should be collected in minimum amount for scientific purposes only. There is a need to make an inventory of local mushrooms for every area with a list indicating the availability status and total embargo on the collection of RET (Rare, Endangered and Threatened) species should be imposed. Pasture management is another area which needs to be looked into. Livestock in agriculture based societies should be managed in a manner which favors their grazing in the wild, pastures, etc. The use of dung as fuel or building material, mowing of grasslands, etc. is destructive for coprophilous mushrooms. Indiscriminate use of chemical fertilizers is another area which needs to be looked into as their accumulation over the years makes the habitats unfavorable for the healthy growth of coprophilous mushrooms. The work needs further extension so as to study the ecological relationships of coprophilous mushrooms with their herbivorous hosts and to unearth the information about rare and ephemeral species which need targeted conservation effort including protection of their habitats.

**Conclusion**

The study revealed that dung is an important substrate which serves as a favorable niche for the growth of a variety of mushrooms. But the natural habitats with dung deposits are getting destroyed because of different developmental activities. Livestock, in agriculture based societies like Punjab state in India, should be managed in a manner which favors their grazing in the wild places. Coprophilous mushrooms must be conserved as they play a significant role in the decomposition of organic matter and continuation of ecological balance on the earth.

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**References**

Allen JW, Gartz J. 1997 – Magic Mushrooms in Some Third World Countries. Psilly Publications and Raver Books Seattle, Washington.

Amandeep K, Atri NS, Munruchi K. 2013a – Diversity of species of the genus *Bolbitius* (Bolbitiaceae, Agaricales) collected on dung from Punjab, India. Mycosphere 4(6), 1053–1064, Doi 10.5943/mycosphere/4/6/3

Amandeep K, Atri NS, Munruchi K. 2013b – Two new coprophilous varieties of *Panaeolus* (Psathyrellaceae, Agaricales) from Punjab, India. Mycosphere 4(3), 619–625, Doi 10.5943/mycosphere/4/3/13

Amandeep K, Atri NS, Munruchi K. 2014 – Taxonomic study on coprophilous species of *Coprinopsis* (Psathyrellaceae, Agaricales) from Punjab, India. Mycosphere 5(1), 1–25, Doi 10.5943/mycosphere/5/1/1

Amandeep K, Atri NS, Munruchi K. 2015a – Diversity of species of the genus *Conocybe* (Bolbitiaceae, Agaricales) collected on dung from Punjab, India. Mycosphere 6(1), 19–42, Doi 10.5943/mycosphere/6/1/4

Amandeep K, Atri NS, Munruchi K. 2015b – Taxonomic study on the coprophilous mushrooms from Punjab, India: new records of family Agaricaceae. CREAM 5(1), 27–45, Doi 10.5943/cream/5/1/5

Angel K, Wicklow DT. 1974 – Decomposition of rabbit feces: An indication of the significance of the coprophilous microflora in energy flow schemes. Journal of Ecology 62, 429–437.

Angel K, Wicklow DT. 1975 – Relationship between coprophilous fungi and fecal substrate in Colorado grassland. Mycologia 67, 63–74.

Anisova LN, Bartoshevich YE, Efremenkova OV, Krasilnikova OL, Kudinova MK, Murenets NV, Klyuev NA, Chernyshev AI, Shorshnev SV, Terentyeva TG, Rudneva NA. 1987 – Isolation and identification of antileukosis substance from *Coprinus radiatus*. Antibiotiki I Meditsinskaya Biotekhnologiya 32, 735–738.

Arora D. 1986 – Mushrooms demystified. A comprehensive guide to the fleshy fungi. Ten Speed Press, Berkeley, California, pp 936.

Atkinson GF. 1961 – Studies of American Fungi– Mushrooms, Edible, Poisonous etc., 2nd ed, Hafner Publishing Company, New York, pp 322.

Atri NS, Kour H. 2005 – Some unrecorded wild mushrooms of Punjab, India. Mushroom Research 14, 56–59.

Atri NS, Kaur A, Kaur M. 2009a – Three new records of coprophilous mushrooms of family Bolbitiaceae from India. Mushroom Research 18 (2), 51–56.

Atri NS, Kaur A, Kour H. 2005 – Systematics and Sociobiology of Termitophilous mushrooms from Punjab. In: Fungi Diversity and Conservation in India (eds JS Dargan, NS Atri, GS Dhingra). Bishen Singh Mahendra Pal Singh, Dehra Dun, UK, India, pp 159–182.

Atri NS, Kaur A, Kour H. 2005a – Wild mushrooms–collection and identification. In: Frontiers in Mushroom Biotechnology (eds RD Rai, RC Upadhyay, SR Sharma). NRCM Solan, Himachal Pradesh, India, pp 9–26.

Atri NS, Kaur A. 2004 – Mushroom flora of Patiala- The genus *Coprinus* Pers. ex Gray. In: Plant Diversity in India (eds JS Dargan, TA Sarma). Bishen Singh Mahendra pal Singh, Dehra Dun, UK, India, pp 427–448.

Atri NS, Kaur M, Kaur A. 2012 – Taxonomic studies on some coprophilous species of *Conocybe* from India. Mushroom Research 21(2), 103–109.

Atri NS, Kour H, Kaur A, Saini MK. 2009b – Mushroom wealth of north–eastern Punjab: their ecology, conservation and screening. In: Germplasm Diversity and Evaluation– Algae, Fungi and Lichens (eds NS Atri, RC Gupta, MIS Sagoo, VK Singhal). Bishen Singh Mahendra Pal Singh, Dehra Dun, UK, India, pp 59–74.

Atri NS, Kumari B, Saini MK. 2010 – Two interesting Lepiotoid mushrooms from North West India. Mushroom Research 19(2), 82–85.

Atri NS, Lakhanpal TN. 2002 – Conservation of Mushroom Biodiversity. Indian Journal of Mushrooms 19(18), 1–9.

Atri NS, Saini SS, Gupta AK, Kaur A, Kour H. 2007 – Documentation of wild mushrooms with edibility potential and their seasonal availability in Punjab. National Symposium on Researches

in Fungal Biology: Emerging Trends, Punjabi University Patiala, pp 67–68 January 30–31, 2007.
Bell A. 1983 – Dung Fungi. An Illustrated Guide to Coprophilous Fungi in New Zealand. Victoria University Press, Private Bag Wellington, pp 88.
Bilgrami KS, Jamalludin, Rizwi AM. 1979 – Fungi of India. Today and Tomorrow's Printers and Publishers, New Delhi, pp 467.
Bilgrami KS, Jamalludin, Rizwi AM. 1991 – Fungi of India. Today and Tomorrow's Printers and Publishers, New Delhi, pp 798.
Bose SR, Bose AB. 1940 – An account of edible mushrooms of India. Science and Culture 6, 141–149.
Botton CR, Siehr DJ. 1975 – Hydroxylagopodin B, a sesquiterpene quinine from a mutant strain of Coprinus macrorhizus var. microsporus. Phytochemistry 14(5&6), 1433.
Chang ST, Hayes WA. 1978 – The Biology and Cultivation of Edible Mushrooms. Academic Press Inc. London, New York, pp 819.
Dhancholia S, Sinha MP. 1990 – Additional studies on Agarics of Orissa II. Geobios New Reports 9, 108–113.
Dickinson C, Lucas J. 1979 – The Encyclopedia of Mushrooms. VNR Colour Dictionary of Mushrooms. G.P. Putnam's Sons, New York.
Dickinson CH, Underhay VHS. 1977 – Growth of fungi in cattle dung. Transactions of the British Mycological Society 82, 174–177.
Didukh MY, Wasser SP, Nevo E. 2004 – Impact of the family Agaricaceae on nutrition and medicine. A.R.A. Gantner Verlag K.G., Ruggell, Liechtenstein, pp 205.
Dutta AK, Pradhan P, Roy A, Acharya K. 2011 – *Volvariella* of West Bengal, India I. Researcher 3(5), 13–17.
Efremenkova OV, Ershova EY, Tolstych IV, Dudnik YV. 2003 – Antimicrobial activity of medicinal mushrooms from the genus *Coprinus* (Fr.) S. F. Gray (Agaricomycetidae). International Journal of Medicinal Mushrooms 5(1), 37–41.
Efremenkova OV, Ershova EY, Tolstych IV, Valentina AZ, Dudnik YV. 2001 – Antimicrobial Activity of *Coprinus* Pers. Isolates. International Journal of Medicinal Mushrooms 3, 138.
Farook VA, Khan SS, Manimohan P. 2013 – A checklist of agarics (gilled mushrooms) of Kerala State, India. Mycosphere 4(1), 97–131, Doi 10.5943 /mycosphere/4/1/6
Ginai MA. 1936 – Further contribution to knowledge of Indian coprophilous fungi. Journal of the Indian Botanical Society 15, 269–284.
Gupta A, Atri NS, Kaur M, Saini SS. 2008b – Studies on the genus *Agaricus* L.: Fr. - IV. The sub genus *Agaricus* section Arvensis Konr. et. Maubl. from North West India. Indian Journal of Mushrooms 26(1&2), 22–30.
Gupta A, Atri NS, Kaur M. 2008a – Studies on the genus *Agaricus* L.: Fr. - V. The sub genus *Agaricus* section Xanthodermatei Sing. Indian Journal of Mushrooms 26(1&2), 38–44.
Guzmán G, Allen JW, Gartz J. 2000 – A worldwide geographical distribution of the neurotropic fungi, analysis and discussion. Anali dei Civeci Musei, Rovereto 14, 189–270.
Guzmán G, Trappe JM. 2005 – The hallucinogenic and non-hallucinogenic species of the genus *Psilocybe* Fayod (Basidiomycotina) in Washington State, USA, new records and a new species. International Journal of Medicinal Mushrooms 7, 583–589.
Guzmán G. 1978 – Variation, distribution, ethnomycological data and relationships of *Psilocybe aztecorum*, a Mexican hallucinogenic mushroom. Mycologia 70, 385–396.
Halfter G, Matthew SE. 1971 – The natural history of dung beetles: A supplement on associated biota. Revista latinoamericana de microbiología 13, 147–163.
Hall IR. 2003 – Edible and poisonous mushrooms of the world. Timber Press, Portland, USA, pp 371, ISBN 0881925861
Hallen HE, Watling R, Adams GC. 2003 – Taxonomy and toxicity of *Conocybe lactea* and related species. Mycological Research 107(8), 969–979.

Hausknecht A, Kalamees K, Knudsen H, Mukhin V. 2009 – The genera *Conocybe* and *Pholiotina* (Agaricomycotina, Bolbitiaceae) in temperate Asia. Folia Cryptogamica Estonica, Fasc 45, 23–47.

Ing B. 1989 – Why not look at the dung fungi? The Mycologist 3, 33.

Ingold CT. 1971 – Fungal spores: their liberation and dispersal. Clarendon Press, Oxford, pp 302.

Jamalludin, Goswami MG, Ojha BM. 2001 – Fungi of India (1989-2001). Forest Pathology Division. Tropical Forest Research Institute, Jabalpur (MP), Publisher Pawan Kumar, Scientific Publishers India.

Justo A, Minnis AM, Ghignone S, Menolli JN, Capelari M, Rodríguez O, Malysheva E, Contu M, Vizzini A. 2010a – Species recognition in *Pluteus* and *Volvopluteus* (Pluteaceae, Agaricales): morphology, geography and phylogeny. Mycological Progress 10, 453–479.

Justo A, Vizzini A, Minnis AM, Menolli Jr N, Capelari M, Rodríguez O, Malysheva E, Contu M, Ghignone S, Hibbett DS. 2010b – Phylogeny of the Pluteaceae (Agaricales, Basidiomycota): Taxonomy and character evolution. Fungal Biology 30, 1–20.

Karun NC, Sridhar KR. 2015 – Elephant dung-inhabiting macrofungi in the Western Ghats. Current Research in Environmental & Applied Mycology 5(1), 60–69, Doi 10.5943/cream/5/1/8

Kauffman CH. 1918 – The Agaricaceae of Michigan. Biological Series 5, Publication 26, Geological and Biological Survey, Lansing, Michigan, pp 110.

Kaul TN, Kachroo JL. 1974 – Common edible mushrooms of Jammu and Kashmir. The Journal of the Bombay Natural History Society 71, 26–31.

Kaur A, Atri NS, Kaur M. 2013a – A new variety of *Rhodocybe popinalis* (Entolomataceae, Agaricales) from coprophilous habitats of India. Journal on New Biological Reports 2(3), 260–263.

Kaur A, Atri NS, Kaur M. 2013b – A new species of *Psathyrella* (Psathyrellaceae, Agaricales) collected on dung from Punjab, India. Journal on New Biological Reports 2(3), 275–280.

Kaur A, Atri NS, Kaur M. 2014a – Two new species of *Panaeolus* (Psathyrellaceae, Agaricales) from coprophilous habitats of Punjab, India. Journal on New Biological Reports 3(2), 125–132.

Kaur A, Atri NS, Kaur M. 2014b – Two new species of *Agaricus* (Agaricaceae, Agaricales) collected on dung from Punjab, India. Kavaka 42, 20–24.

Kaur A, Atri NS, Kaur M. 2014c – Diversity of coprophilous species of *Panaeolus* (Psathyrellaceae, Agaricales) from Punjab, India. Biodiversitas 15(2), 115–130, Doi 10.13057/biodiv/d150202

Kaur A, Kaur M, Atri NS. 2013c. *Protostropharia semiglobata* var. *punjabensis*: A new coprophilous agaric from India. Kavaka 41, 11–14.

Kaur M, Kaur B, Kaur H, Atri NS. 2011b – The Genus *Psathyrella* (Fr.) Quél from India. Journal of Mycology and Plant Pathology 41(4), 584–588.

Kaur M, Kaur H, Atri NS, Singh Y. 2011a – Genus *Rhodocybe* Maire from India- new records. Mushroom Research 20 (1), 63–66.

Kaur M, Kour H, Atri NS. 2008 – Study of Punjab Mushrooms. Indian Journal of Mushrooms 26, 14–17.

Kaushal SC, Grewal K. 1992 – Coprophilous fungi from Chattbir. National Symposium on Botanical Research Trends and Achievements. Department of Botany, Punjab University, Chandigarh, pp 19–20, 30–31, March, 1992.

Kerrigan RW. 1986 – Agaricaceae. In: Agaricales of California (ed HD Thiers). Mad River Press, Eureka CA, pp 62.

Kirk PF, Cannon PF, Minter DW, Stalpers JA. 2008 – Ainsworth and Bisby's Dictionary of Fungi, 10th ed, CABI Bioscience, CAB International, UK.

Kornerup A, Wanscher JH. 1978 – Methuen Handbook of Colour, 3rd ed, Eyre Methuen, London.

Kumar M, Harsh NSK, Prasad R. 2014 – *Conocybe apala* (Fr.: Fr.) Arnolds, *Helvella solitaria* P. Karst. and *Hygrocybe miniata* (Fr.) P. Kumm.; three new mushrooms from India. CREAM 4(1), 100–105, Doi 10.5943/ream/4/1/8

Kumar RN, Pasricha R, Singh N, Mukherjee KG. 1995 – Taxo-ecological studies of coprophilous fungi- a review. In: Advances in Ecology and Environmental Sciences (eds PC Mishra, N

Behera, BK Senapatic, BC Guru). Ashish Publishing House, New Delhi, pp 651, ISBN 81-7024-676-8
Kumar TKA, Manimohan P. 2009 – The genus *Lepiota* (Agaricales, Basidiomycota) in Kerala state, India. Mycotaxon 107, 105–138.
Kuo M. 2005 – *Chlorophyllum molybdites*, retrieved from the MushroomExpert.Com Web site: http://www.mushroomexpert.com/chlorophyllum_ molybdites. html
Lambourne LJ, Reardon TF. 1962 – The use of seasonal regressions in measuring feed intake of grazing animals. Nature Land 196, 961–962.
Lodha BC. 1974 – Decomposition of digested litter. In: Biology of plant litter decomposition (eds CH Dickinson, GJF Pugh). Academic Press, New York, pp 213–241.
Mahju NA. 1933 – A Contribution to our knowledge of Indian coprophilous fungi. Journal of the Indian Botanical Society 12, 153–164.
Manimohan PK, Thomas A, Nisha VS. 2007 – Agarics on elephant dung in Kerala State, India. Mycotaxon 99, 147–157.
Manku DS. 2002 – Geography of Punjab. Kalyani Publishers, New Delhi.
Matheny PB, Curtis JM, Hofstetter V, Aime MC, Moncalvo JM, Ge ZW, Slot JC, Ammirati JF, Baroni TJ, Bougher NL, Hughes KW, Lodge DJ, Kerrigan RW, Seidl MT, Aanen DK, DeNitis M, Daniele GM, Desjardin DE, Kropp BR, Norvell LL, Parker A, Vellinga EC, Vilgalys R, Hibbett DS. 2006 – Major clades of Agaricales: a multilocus phylogenetic overview. Mycologia 98(6), 982–95.
Moncalvo JM, Lutzoni FM, Rehner SA, Johnson J, Vilgalys R. 2000 – Phylogenetic relationships of agaric fungi based on nuclear large subunit ribosomal DNA sequences. Systematic Biology 49, 278–305.
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 OJ. 2002 – One hundred and seventeen clades of euagarics. Molecular Phylogenetics and Evolution 23, 357–400.
Morrison FB. 1959 – Feeds and Feeding. Morrison Publishing Company, Clinton, Iowa.
Murrill WA. 1922 – Dark spored agarics-III Agaricus. Mycologia 14, 200–221.
Natarajan K, Raaman N. 1984 – South Indian Agaricales. A preliminary study on some dark spored species. International Books and Periodicals Supply Services, New Delhi, pp 1–204.
Natarajan K, Kumaresan V, Narayanan K. 2005 – A checklist of Indian Agarics and Boletes (1984–2002). Kavaka 33, 61–128.
Natarajan K, Raaman N. 1983 – South Indian Agaricales. Bibliotheca Mycologica 89, 1–203.
Natarajan K. 1977 – A new species of *Termitomyces* from India. Current Science 46(19), 679–680.
Noordeloos ME, Kuyper TW, Vellinga EC. 2005 – Flora Agaricina Neerlandica 6: Coprinaceae and Bolbitiaceae. Taylor and Francis, Boca Raton, FL, pp 227.
Noordeloos ME, Vrinda KB, Manimohan P. 2007 – On two remarkable brown-spored agarics from Kerala state, India. Fungal Diversity 27, 145–155.
Ohtsuka S, Ueno S, Yoshikumi C, Hirose F, Ohmura Y, Wada T, Fujii T, Takahashi E. 1973 – Polysaccharides having an anticarcinogenic effect and a method of producing them from species of Basidiomycetes. United Kingdom Patent 1331513–A.
Pacioni G. 1985 – The McDonald Encyclopedia of Mushrooms and Toadstools. MacDonald and Company (Publishers) Limited, London, England.
Pegler DN, Piearce GD. 1980 –The edible mushrooms of Zambia. Kew Bulletin 35(3), 477–482.
Pegler DN. 1977 – A Preliminary Agaric flora of East Africa. Kew Bulletin Additional Series 6, London, pp 615.
Pegler DN. 1983 – Agaric flora of the lesser Antitles. Kew Bulletin Additional Series 9, London, pp 668.
Pegler DN. 1986 – Agaric flora of Sri Lanka. Kew Bulletin Additional Series 12, London, pp 514.
Piontelli E, Cruz LR, Toto ASM. 2006– Coprophilous fungal community of wild rabbit in a park of a hospital (Chile): A taxonomic approach. Boletin Micologico 21, 1–17.

Prydiuk MP. 2007a – New records of *Conocybe* species from Ukraine. I. The sections Mixtae and Pilosellae. Česká Mykologie 59 (1), 25–38.
Prydiuk MP. 2007b – New records of *Conocybe* species from Ukraine. II. The section Conocybe. Česká Mykologie 59(1), 39–50.
Purkayastha RP, Chandra A. 1985 – Manual of Indian Edible Mushrooms. Jagmander Book Agency, New Delhi.
Pushpa H, Purushothama KB. 2011 – *Leucocoprinus* Pat. (Agaricaceae, Agaricales, Basidiomycota) in Bengaluru, Karnataka state, India. World Applied Sciences Journal 14(3), 470-475, ISSN 1818-4952
Pushpa H, Purushothama KB. 2012 – Biodiversity of mushrooms in and around Bangalore (Karnataka), India. American-Eurasian Journal of Agricultural and Environmental Sciences 12(6), 750–759.
Rawla GS, Sarwal BM, Arya S. 1982 – Agarics new to India I. Nova Hedwigia 36, 433–43.
Rea C. 1922– British Basidiomycetaceae: A Handbook to the Larger British Fungi. Cambridge University Press, Cambridge, England, pp 799.
Richardson MJ. 1998 – New and interesting records of coprophilous fungi. Botanical Journal of Scotland 50, 161–175.
Richardson MJ. 2001 – Diversity and occurrence of coprophi1ous fungi. Mycological Research 105, 387-402.
Richardson MJ. 2003 – Coprophilous fungi. Field Mycology 4, 41–43.
Saini MK, Singh Y, Kaur H, Atri NS. 2008-2009 – The genus *Volvariella* Speg. from North India. Journal of Punjab Academy of Sciences 5-6(1&2), 52–56.
Sathe AV, Deshpande S. 1980 – *Agaricales* (Mushrooms) of Maharashtra, MACS Monograph 1, 9–42.
Sathe AV, Rahalkar SR. 1978 – *Agaricales* from South-West India-III. In: Indian Mushroom Science (eds CK Atal, BK Bhat, TN Kaul). Indo–American Literature House, USA.
Shaffer RL. 1957 – *Volvariella* in North America. Mycologia 49(4), 545–579.
Singer R. 1986 – The Agaricales in Modern Taxonomy, 4th ed, Sven Koeiltz Scientific Books, Germany, pp 981.
Smith AH. 1949 – Mushrooms in their Natural Habitats. Hafner Press, New York, pp 626.
Smith AH. 1972 – The North American Species of *Psathyrella*. Memoris of the New York Botanical Garden 24, pp 633.
Stamets P. 1996 – Psilocybin Mushrooms of the World. Ten Speed Press, Berkeley, ISBN 0-9610798-0-0
Sundberg WJ. 1971 – A new species of *Lepiota*. Mycologia 63(1), 79–82.
Sundberg WJ. 1989 – *Lepiota* sensu lato in California III-Species with a Hymeniform pileipellis. Mycotaxon 34(1), 239–248.
Thomas KA, Hausknecht A, Manimohan P. 2001 – Bolbitiaceae of Kerala State, India, new species and new and noteworthy records. Österreichische Zeitschrift für Pilzkunde 10, 87–114.
Thomas KA, Manimohan P. 2002 –The genus *Psilocybe* in Kerala state, India. Mycotaxon 83, 195–207.
Uljé CB, Bas C. 1988 – Studies in *Coprinus* I. Persoonia 13, 433–448.
Uljé CB, Bas C. 1991 – Studies in *Coprinus* II. Persoonia 14, 275–339.
Uljé CB, Noordeloos ME. 1993 – Studies in *Coprinus* III. Persoonia 15, 257–301.
Uljé CB, Noordeloos ME. 1997 – Studies in *Coprinus* IV. Persoonia 16, 265–333.
Uljé CB, Noordeloos ME. 1999 – Studies in *Coprinus* V. Persoonia 17, 165–199.
Van de Bogart F. 1976 – The Genus *Coprinus* in Western North America. Mycotaxon 4(1), 233–275.
Van de Bogart F. 1979 – The sections of *Coprinus* present in Western United States. Mycotaxon 9(1), 348–357.
Vellinga EC. 2001 – *Macrolepiota* Sing., *Leucocoprinus* Pat., *Leucoagaricus* (Locq) Sing., *Lepiota* (Pers.: Fr.) S.F.Gray, *Cystolepiota* Sing., *Melanophyllum* Velen. In: Flora Agaricina Neerlandica (eds TW Kuyper, EC Vellinga). Swets and Zeitlinger, Lisse, 5, 64–162.
Vellinga EC. 2003 – *Chlorophyllum* and *Macrolepiota* (Agaricaceae) in Australia. Australian Systematic Botany 16, 361–370.

Vrinda KB, Pradeep CK, Mathew S, Abraham TK. 1999 – Agaricales from Western Ghats-VI. Indian Phytopathology 52(2), 198–200.
Watling R, Bigelow HE. 1983 – Observations on the Bolbitiaceae–22. Mycotaxon 17, 377–397.
Watling R, Gregory NM. 1987 – British Fungus Flora-Agaric and Boleti 5. Strophariaceae and Coprinaceae. Royal Botanic Gardens, Edinburgh.
Watling R, Taylor GM. 1987 – Observations on the Bolbitiaceae. Bibliotheca Mycologia, 27 J Cramer, Berlin, Stuttgart.
Watling R. 1982 – British Fungus Flora- Agaric and Boleti 3. Bolbitiaceae: *Agrocybe*, *Bolbitius*, *Conocybe*, Edinburgh, HMSO, UK
Watling R. 1985 – The Agaricales of Iceland- VI. Icelandic species of Bolbitiaceae. Observations on the Bolbitiaceae: 25. Acta Botanica Islandica 8, 3–19.
Webster J. 1970 – Coprophilous Fungi: Presidential Address. Transactions of the British Mycological Society 54, 161–180.
Webster J. 1999 – Fungi of dung. In: The biodiversity of animal dung (ed J Cox). Hampshire and IOW Wildlife Trust, Eastleigh, Hants.
Zahid S, Udenigwe CC, Ata A, Eze MO, Segstro EP, Holloway P. 2006 – New bioactive natural products from *Coprinellus micaceus*. Natural Products Research 20(14), 1283–1289.