



***Xerula radicata* var. *setosa* var. nov. and three new records of the family *Physalacriaceae*, Agaricales from the Indian subcontinent**

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Abstract

As an outcome of fungal forays, a number of collections of genera *Strobilurus* and *Xerula* were made from Kashmir, Himalaya. These collections were analyzed taxonomically as per the standard methodology. In the present paper, three species of the genus *Xerula* viz. *X. furfuracea*, *X. radicata* var. *setosa* var. nov., *X. kenyae* and one species of the genus *Strobilurus* namely *S. tenacellus* are discussed. Among these species, one new variety is proposed viz. *Xerula radicata* var. *setosa* var. nov. and the other three species are reported for the first time from India. Full descriptions, field photographs, microphotographs, drawings of macroscopic and microscopic features and a key to the explored taxa are provided.

Keywords – Inamyloid basidiospores – *Strobilurus* – Taxonomic Key – *Xerula*

Introduction

The family Physalacriaceae was originally described by Corner (1970) and revised by Berthier (1985). By using molecular analyses monophyly was confirmed in the Physalacriaceae (Moncalvo et al. 2002, Matheny et al. 2007). A review of the Physalacriaceae, based on morphology as well as phylogenies identified several new genera and the systematics of the *Oudemansiella/Xerula* complex has also been drastically revised (Petersen & Hughes 2010). The family Physalacriaceae falls under the order Agaricales and typified by the genus *Physalacria* (Peck 1882). Approximately 21 genera have been reported worldwide that falls under the family Physalacriaceae (Park et al. 2017). This family is characterized in possessing a highly variable fruiting bodies ranging from agaricoid, secotioid, cantharelloid, corticoid and clavarioid (Henkel et al. 2010, Moreau et al. 2015). This family is distinguished by a monomitic hyphal system i.e. only generative hyphae are produced with clamp connections, basidiospores are smooth, thin walled, fusiform, ellipsoidal, lacrimiform or cylindrical and the basidia are clavate with two to four basidiospores (Cannon & Kirk 2007). Species in the family Physalacriaceae are mostly saprobic, growing on decaying leaves and wood while a few species are parasitic (Cannon & Kirk 2007).

The fungal genus *Strobilurus* occurs within the family Physalacriaceae and is represented approximately by 13 species worldwide (Redhead 1980, Desjardin 2000, Kirk et al. 2008, Katumoto 2010, Terashima et al. 2016, Qin et al. 2018) while Mycobank (2020) documented 23 species worlds over. However, from India only two species of this genus have been reported so far (Rawla et al. 1984, Upadhyay & Sohi 1987, Upadhyay et al. 2017). Genus *Strobilurus* is

characterised in possessing a collybioid basidiocarp, lamellae are adnexed to almost free, stipe with a long tapering rooting base or pseudorrhiza, veil is absent and spore print is white while anatomically the basidiospores are smooth, thin walled and inamyloid, the hymenial cystidia and dermatocystidia are both present in the cortical layers of pileus and stipe and the pileus cuticle is an cellular epicutis or hymeniderm. Species of this genus usually grow on deep rooting buried cones of various coniferous trees, on seed pods or fruits of *Magnolia*, *Liquidambar* as well as wood and branches of other angiosperms and conifers, including *Cryptomeria* and perhaps on *Betula* (Hongo 1955, Wells & Kempton 1971, Redhead 1980, Bessette et al. 1993, Katumoto 2010). Most taxa are described to be directly related to the substrate, while a few can be substrate generalists (Qin et al. 2018).

Genus *Xerula* is morphologically characterised in possessing a collyboid fruiting body, colour of the cap varies from gray, brown to black, pileus glabrous or villose, dry or viscid, lamellae are whitish, adnate, sinuate or subdecurrent, distinct, broad, stipe is erect with a tapering rooting base and the spore print is white in colour. Microscopically, basidiospores are smooth or spiny, globose to subglobose or broadly ellipsoid and are inamyloid, pleurocystida and cheilocystidia are present and are fusiform or clavate, pileus cuticle is an hymeniderm with or without setae or pileal hair on pileus and stipe and the clamp connections are present (Ronikier 2003). Genus *Xerula* is represented by 15 species worlds over Kirk et al. (2008) while the latest record on Mycobank (2020) documents 99 species of this genus. However, from India 6 species of this genus have been reported so far (Sathe & Kulkarni 1980, Farook et al. 2013, Kumar et al. 2015).

Materials & Methods

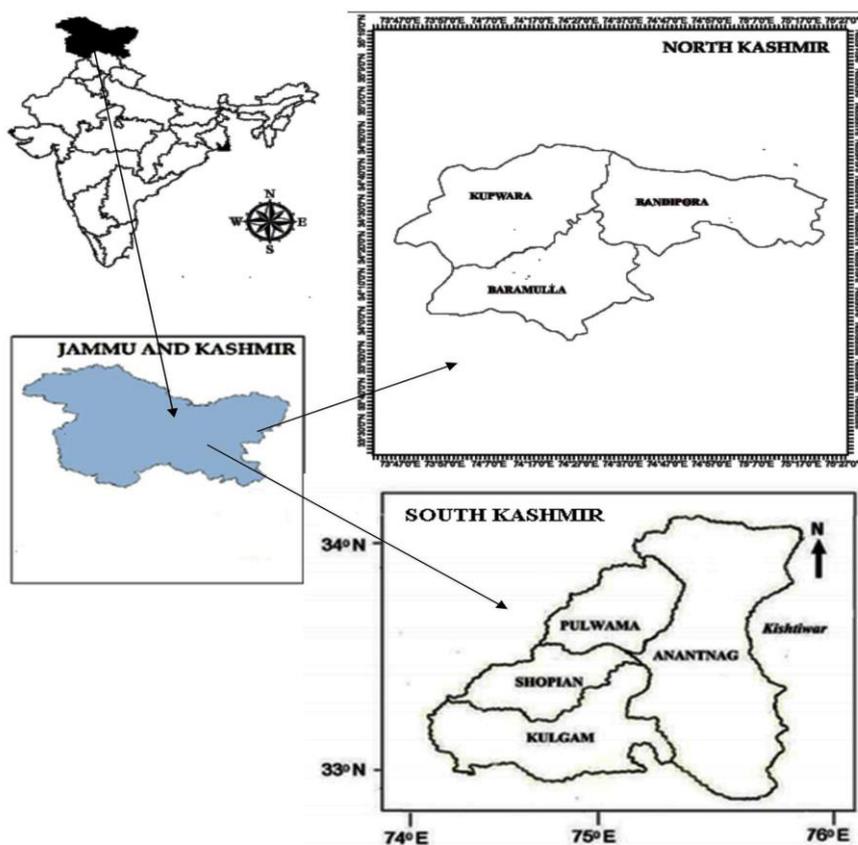
Study area

Jammu and Kashmir, the paradise on earth is one of the largest states of India which is located in the extreme North of the country, it comprises of the mighty Himalayas decorated with snowcapped mountains, green grasslands which are rich in flora and fauna. The area is bounded on the North and East by China (Xinjiang and Tibet), Northwest by Afghanistan (Wakhan Corridor), West by Pakistan (Khyber Pakhtunkhwa and Punjab) and on the South by India (Punjab and Himachal Pradesh) respectively Tamang & Prakash (2009). It is rich in forests and occupying 51% of its total geographic area (Anon 1996). The present study area falls under the Kashmir valley and lies between the coordinates 34°10' North latitude and 74°30' East longitude which is largely defined by its geographic location with Karakoram Range in the north, Pir Panjal in the south and west and in the east by the Zaskar range Negi (1986). It has a total area of 68,000 sq mi (180,000 km²) Frederic (1875). Phytogeographically, the forests in Kashmir region vary from temperate (1700–2900 m), subalpine (3100–3500 m) to alpine forests (3500 m and above). Being rich and unexplored in fungal diversity the present area i.e. North and South Kashmir was selected for undertaking the studies on the diversity of agarics. Politically, North Kashmir comprises of three districts viz, Baramulla, Kupwara and Bandipora and South Kashmir viz. Kulgam, Anantnag, Pulwama and Shopian. Geographically North Kashmir lies between the coordinates 34.2865°N, 74.4634°E with altitude ranging from 1600–4000 m receiving an annual rainfall ranging between 600 – 900 mm while South Kashmir lies between 33°–20' to 34°–15'N latitude and 74° – 30' to 75°–35'E longitude with altitude ranging between 1700 to more than 3048m and average annual rainfall 100–155mm. The area possesses a primary place in the diversity and galaxy of macrofungi due to ample agroclimatic variations, undulating topography and diverse physiography but understanding of the macrofungal flora of the Kashmir is still in an exploratory or pioneer stage and undoubtedly there are many more species to be recorded (Watling & Abraham 1992). The information with respect to the fungal forays planned regarding various localities and sublocalities of North and South Kashmir surveyed during the present investigations along with their location (Latitude and Longitude), altitudinal range and forest type surveyed are shown in the Table 1, Fig. 1. The diversity of these agarics in this specific region is largely determined by the vegetation and climate

of an area. Vegetation too has profound influences on the species richness and composition of macrofungi (Villeneuve et al. 1989). In general vegetation is mainly determined by soil, climate and geology of the region (Champion & Seth 1968). The study also examines the data with respect to the seasonal availability, habit, habitat, edibility status and the range of distribution of these identified taxa.

Table 1 Distribution, habitat, seasonal availability and putative ECM association of investigated fungal taxa

Name of genus and species	Locality (Altitude)	Date of collection	Growing habit	Habitat/ ECM association	Herbarium numbers
Genus <i>Strobilurus</i> Singer					
<i>S. tenacellus</i>	Gulmarg (2750 m)	5 th May, 2013	Scattered groups	Coniferous needles of <i>Pinus</i>	PUN 9263
Genus <i>Xerula</i> Maire					
<i>X. kenya</i>	Verinag (2300 m)	11 th August, 2015	Solitary	Coniferous forest on leaf litter of <i>Pinus wallichiana</i>	PUN 9040
<i>X. radicata</i> var. <i>setosa</i> var. nov.	Verinag (2300 m)	11 th August, 2015	Solitary	Coniferous forest on leaf litter	PUN 9042
<i>X. furfuracea</i>	Khadgu Manglu (2150 m)	17 th August, 2015	Solitary	Coniferous forest on humicolous soil	PUN 9259



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Fig. 1 – Magnified Map depicting North and South Kashmir, India (Statistical analysis of GPS trace data; Wani 2019, Malik et al. 2020).

Collection of material

Collections were made on routine mycological field visits to the forests of North and South Kashmir. For the purpose of making collections from the field, field kit was prepared having all the

equipment required for collecting the fruitbodies from the field. This collection kit consisted of a collection bag with accessories like knife, waste newspapers, hand lens, camera, paper and pen to take field notes. The primary data with respect to the locality, its latitude, longitude, altitude, habit, soil types, soil pH, forest type along with the date of collection and the field photograph numbers were noted down on the field key in the field itself. While collecting the specimens, care was taken to collect the fresh and healthy carpophores and to avoid old decaying fruitbodies or those infected with insects etc. Precautions were taken to avoid mixing of all the collections. For this purpose, each collection was wrapped individually. Every effort was made to collect the sociobiological information by interacting with the local people in the field regarding the particular agarics during collections. Collections were taken to the temporary laboratory set up where they were further analysed, dried and packed.

Morphological characteristics

The morphological characters with respect to the shape, colour and size of carpophore, striated or non-striated cap margin, presence or absence of universal veil, volva, annulus, attachment of gills, colour changes of the carpophore parts, etc. were documented as per the standard format given by Atri et al. (2005, 2017). The terminology of Kornerup & Wanscher (1978) was used for recording the colour of various parts of the carpophore, and spore print, etc.

Spore print

Spore print being a key characteristic in the identification of agarics and in order to note down the colour of the spore print white coloured reference cards measuring 13.5 × 5.0 cm were used. Fresh and mature carpophores were selected for obtaining a spore print. A triangular piece of the cap of the carpophore was cut towards the attachment of the stipe, and placed with blades facing downwards on a post card sized white paper marked with the appropriate collection number, along with a wet cotton plug in order to provide humidity for the pileus to remain turgid and this arrangement was covered with a petriplate and left undisturbed for one hour. Although sincere efforts were made to get the spore print for all the collections but in order to get a thick spore print the time required for smaller agarics with thin texture is more as compared to the larger fleshy basidiocarps.

Drying and preservation

A small portion of the cap, stipe and volva if present were preserved in liquid preservative (25 ml Rectified alcohol + 5 ml Formalin + 70 ml distilled H₂O, Hawksworth et al. 1995). The major portion of the same collection was hot air dried. For this purpose, especially designed portable and foldable three chambered wooden drier was used (Atri et al. 2005, 2017). The larger and stout specimens were dried in the lower most and middle chamber of the drier whereas the smaller and delicate ones were put in the upper chamber of the drier. During drying, the temperature inside the drier was maintained between 40-45°C. The dried material was finally packed in the cellophane paper bags, the appropriate collection number was put on these packets along with a few crystals of 1, 4 para- dichlorobenzene (Smith 1949). Each such packet was separately wrapped in a standard packet (15.0 x 12.0 cm) made from bond paper. The relevant data concerning each specimen was pasted on the packet. These herbarium packets were vertically arranged in the cardboard boxes, in order to avoid damage to the specimen due to mutual pressure. All the collections were deposited in the herbarium of Botany Department, Punjabi University, Patiala under PUN, an abbreviation allotted by the International Bureau for plant taxonomy and nomenclature of the International association for plant taxonomy, Netherlands (Holmgren & Keuken 1974) to the Herbarium of Botany Department, Punjabi University, Patiala. Jayasiri et al. (2015) was followed to register facesoffungi numbers.

Chemical reactions

The chemical colour reactions being significant in mushroom systematics can be used for the

taxonomic segregation and identification of gilled fungi. In the taxonomic treatment the chemical colour changes carried out on various parts of the carpophore provide vital information, in addition to the morphological characters. Various chemical reactions used in the study were performed on the surface of the fresh fruiting body as well as for its anatomical details are discussed below:

Congo red (2 g Congo Red dissolved in 100 ml Distilled Water): After the application of this chemical the Camera Lucida drawings become easy and clear for making microscopic observations.

Melzer's Reagent or Iodine Test (1.5 gms of Potassium Iodide + 0.5 gms Iodine + 20 ml Distilled Water + 22.0 gms Chloral Hydrate): In this reagent amyloidy i.e. basidiospore wall turns greyish blue, bluish black or nearly black or inamyloidy in which the basidiospore wall remains hyaline.

Results

Strobilurus tenacellus (Pers.) Singer, Persoonia 2 (3): 409 (1962).

Figs 2–4

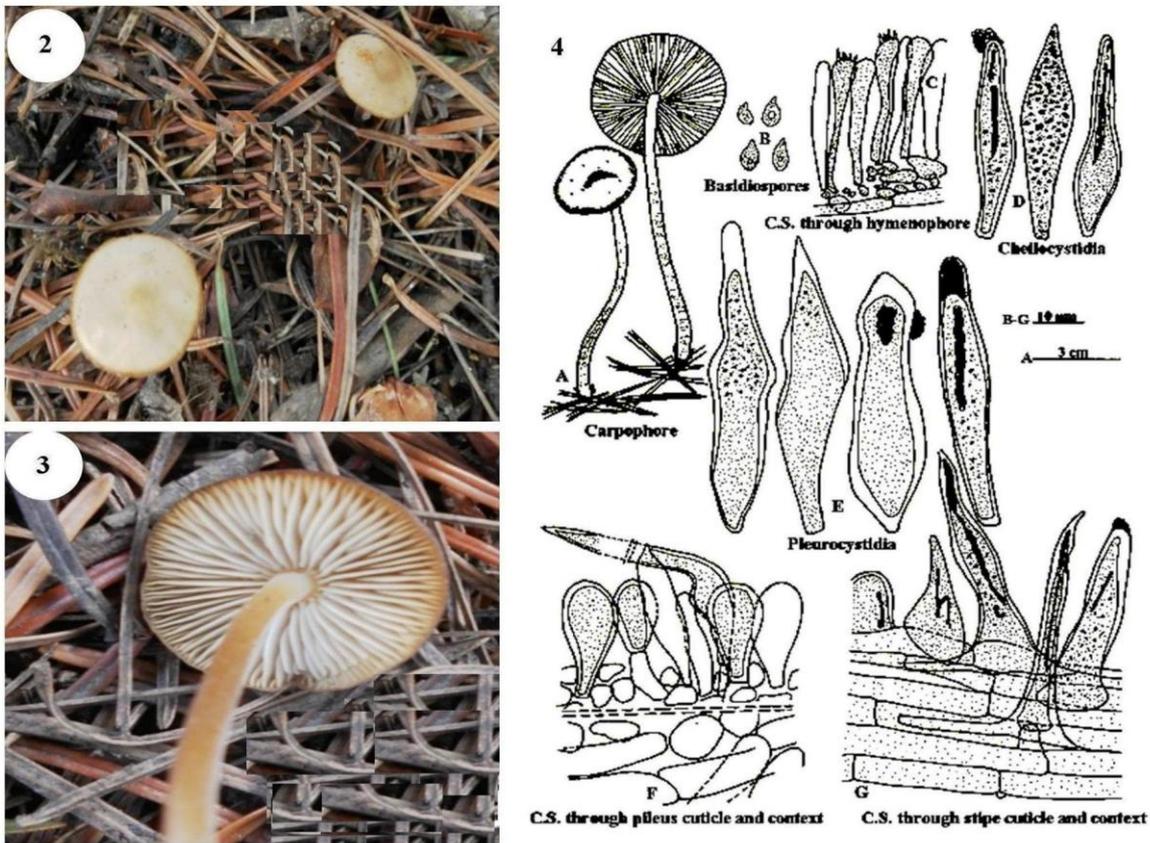
Mycobank number: MB339801; Facesoffungi number: FoF09507

Basidiocarps 9.2–10.0 cm in height. Pileus 2.5–4.5 cm broad; convex; umbonate, umbo obtuse; margin irregular, splitting at maturity, feebly striate towards margins; surface yellowish white (2A₂) with pale yellow (4A₃) to brownish orange (5C₄) centre and brownish orange (5C₅–5C₆) along margins in young carpophores, light brown (7D₄) to brown (7E₅) in mature carpophores; moist; cuticle half peeling; flesh up to 0.1 cm thick, white, unchanging; odor mild. Pileal veil absent. Lamellae adnexed to somewhat free, distant, unequal, not in series, extending beyond the gills, moderately broad (up to 0.2 cm), creamy white to light orange (5A₄), brownish orange (5C₆) to brownish grey (6C₂) towards edges, unchanging; gill edges serrate; lamellulae present. Stipe central, 7.5–9.4 cm long, 0.2–0.3 cm broad, equal in diameter throughout with a long rooting base, surface pale orange (5A₃) to light orange (5A₄) to greyish orange (6B₅) to brownish orange (6C₅), unchanging; hollow; scaly, scales floccose towards apex and appressed fibrillose below; exannulate. Basidiospores 3.32 (4.15)–7.47 × 3.32–4.15 (4.98) μm, Q = 1.5, elliptical, smooth, inamyloid, granular, guttulate, one guttule per spore; apiculate, apiculus up to 1.66 μm long, excentric. Basidia 20.0–31.5 × 4.15–6.64 μm, claviform to cylindrical, granular, without basal clamps; bisterigmate to tetrasterigmate; sterigmata 3.3–5.81 μm long, granular. Pleurocystidia 44.82–66.4 × 8.3–15.0 μm, fusoid ventricose, double walled, densely granular with thick granules, encrusted outer wall, abundant. Cheilocystidia 36.52–63.08 × 6.64–13.28 μm, similar in shape to pleurocystidia, encrusted, abundant; gill edges heteromorphous. Hymenophoral trama regular. Pileus cuticle cellular, hymeniderm made up of 6.64–14.11 μm broad pyriform cells; pilocystidia slender fusiform with pointed ends, double walled, granular, much protruding out of the hymeniderm; context made up of intermixed 10.0–20.75 μm broad, cellular elements and 8.3–20.0 μm broad, septate, hyphae. Stipe cuticle hyphal, made up of longitudinally tangled, septate, granular, 5.0–10.0 μm broad hyphae, giving rise to bunches of caulocystidia not forming a regular turf; caulocystidia 25.0–58.0 × 6.64–13.28 μm, subulate with a broadened foot, thickly granular; context hyphal, made up of septate, thin walled, 5.0–15.0 μm broad hyphae. Clamp connections present throughout.

Collection Examined – Jammu and Kashmir, Baramulla, Gulmarg (2750 m) 34° 04.461' N – 074° 22.430' E growing in scattered groups on needles of conifers of *Pinus*, Naseema Aqbar Wani, PUN 9263, May 5th, 2013.

Distribution and Ecology – Breitenbach & Kränzlin (1991) collected *Strobilurus tenacellus* (Pers.) Singer, from Lucerne (Friedental), growing on buried cones of *Pinus silvestris* in the month of April at 450 m altitude. This species was also found growing on buried cones of *Pinus silvestris*, *Pinus nigra* and occasionally on cones of *Picea* in coniferous or mixed forests between March to June from Western coastal regions, in the Pleistocene districts as reported by Bas et al. (1999). Qin et al. (2018) reported this species growing on the cones of *Pinus silvestris* during spring season from Europe. The present collection has been found growing in scattered groups on needles of conifers in the month of May at an altitude 2750 m.

Notes – The morphology and the microscopic features of the above examined collection matches well with the description provided for *Strobilurus tenacellus* (Pers.) Singer, by Breitenbach & Kränzlin (1991), Bas et al. (1999) and Qin et al. (2018). This species is recognized by the presence of characteristic pilocystidia on the pileus cuticle and tufts of caulocystidia on the stipe cuticle, further the pleurocystidia and cheilocystidia are not claviform and non encrusted as in *S. stephanocystis*, they are fusoid ventricose with encrustations which are typical of *S. tenacellus* as described by Breitenbach & Kränzlin (1991). It is recorded for the first time from India.



Figs 2–4 – *Strobilurus tenacellus*: 2 Carpophores growing in their natural habitat on needles of conifers of *Pinus*. 3 Under view of cap. 4 Camera Lucida drawings (A Carpophores. B Basidiospores. C C.S. through hymenophore. D Cheilocystidia. E Pleurocystidia. F C.S. through pileus cuticle and context. G C.S. through stipe cuticle and context).

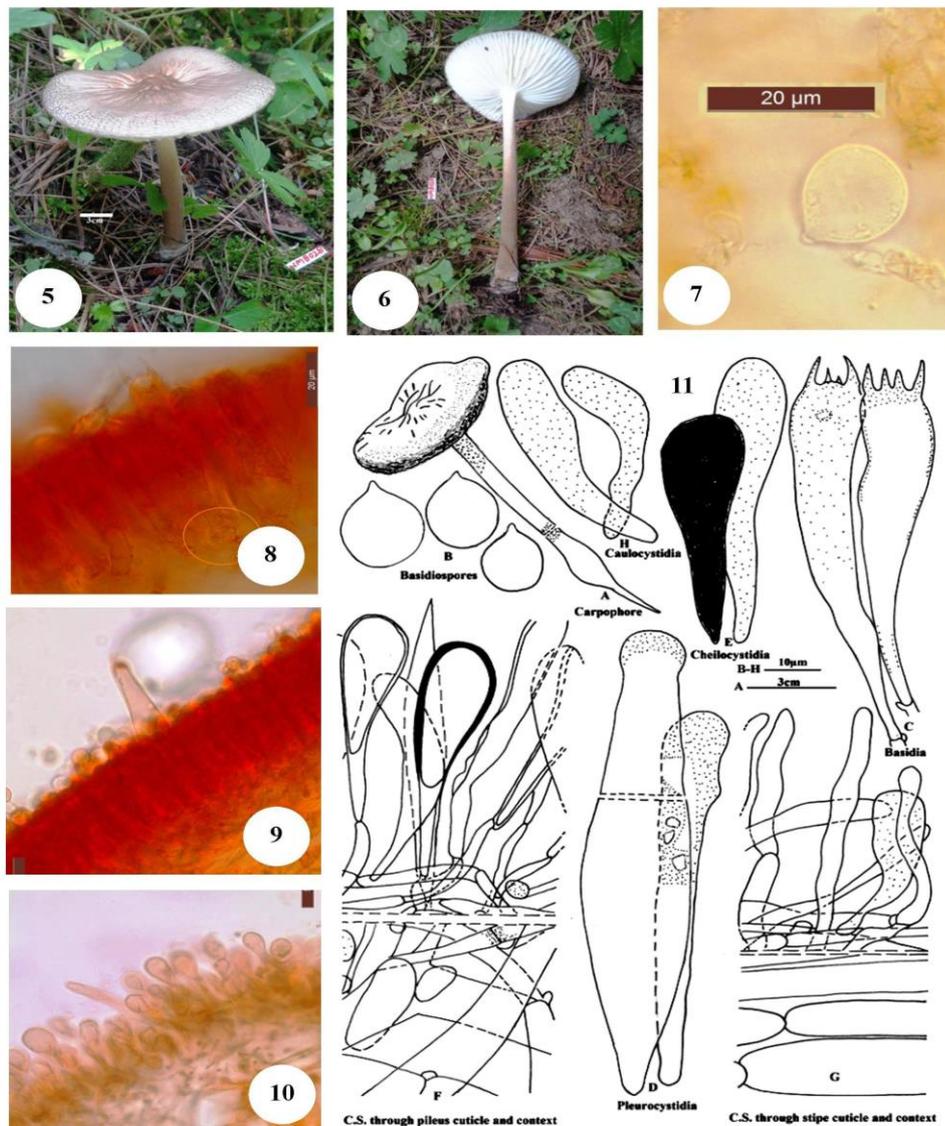
Xerula kenya R.H. Petersen, Fungal Diversity 30: 132, 2008.

Figs 5–11

Mycobank number: MB511154; Facesoffungi number: FoF09508

Basidiocarp up to 13.5 cm in height. Pileus up to 6.0 cm broad, applanate; subumbonate; streaked, radiating from umbo; surface reddish brown (7C₅) in the centre, greyish red (8C₃) at margin; dry; margin regular; cuticle fully peeling; flesh up to 0.5 cm thick, white, unchanging; odor mild. Spore print creamy white. Lamellae up to 0.8 cm broad, adnate to decurrent, toothed, close, unequal, present in 4 tiers, creamy white, unchanging; lamellulae present; gill edges smooth. Stipe excentric, up to 12.0 cm long (excluding rooting base), up to 0.4 cm broad above, up to 1.0 cm broad near base; distinctly bulbous with 2.5 cm long rooting base; surface pale red (8B₃), creamy white near apex; white mycelium present at base; surface furfuraceous, scaly, scales pruinose to fibrillose; hairy; solid; exannulate. Basidiospores 12.8–17.6 × 11.2–16.8 μm, Q = 1.1, globose to ellipsoidal, hyaline, smooth, single thick walled, inamyloid; apiculate, apiculus 0.83–1.6 μm long. Basidia 64.0–104.0 × 9.6–14.4 μm, clavate, granular, clamp connections present at base,

tetrasterigmate; sterigmata 4.8–6.4 μm long, granular. Pleurocystidia 56.0–112 \times 10.4–24.0 μm , clavate to ventricose, utriform with broad to capitate apex, granular in upper half, much protruding from basidial layer, not deeply seated; cheilocystidia 40.0–64.0 \times 9.6–16.0 μm , clavate, granular, consisting yellowish content. Hymenophoral trama regular. Gill edges heteromorphous. Pileus cuticle hyphal, ixocutis, made up of 2.4–6.4 μm broad, septate, horizontally entangled hyphae giving rise to a regular turf of pilocystidia intermixed with occasionally present thick double walled pileal hairs tapering with narrow to rounded tips, rarely inflated; pilocystidia 40.0–104.0 \times 7.2–19.2 μm broad, clavate to sphaeropedunculate, often pedicillate, double walled with yellow content; context hyphal, made up of 4.8–16.0 μm broad, septate, irregularly placed, hyaline, septate, rarely clamped hyphae. Stipe cuticle hyphal, made up of 1.6–4.0 μm broad, longitudinally tangled, septate, hyaline hyphae, giving rise to a regular turf of 3.2–8.0 μm broad, septate, rarely clamped, branched, hyaline, projecting hyphae along with rare caulocystidia which gives scabrous lacerate appearance to the stipe; caulocystidia 32.0–48.0 \times 8.0–12.8 μm broad, clavate, granular, not commonly present; context hyphal, made up of 8.0–16.0 μm broad, longitudinally placed, hyaline, inflated hyphae. Clamp connections present.



Figs 5–11 – *Xerula kenya*. 5 Carpophore solitary with applanate cap and surface with radiating streaks from umbo. 6 Underview of cap with lamellae and furfuraceous hairy stipe. 7 Microphotograph of basidiospore. 8 C.S. through hymenophore bearing basidia with clamp connection at base. 9 Hymenophore with Pleurocystidia. 10 C.S. through gelatinized pileus cuticle

and context showing turf of pilocystidia intermixed with occasionally present thick double walled pileal hair. 11 Camera Lucida drawings (A Carpophore. B Basidiospores. C C.S. through hymenophore. D Pleurocystidia. E. Cheilocystidia F C.S. through pileus cuticle and context. G C.S. through stipe cuticle and context. H Caulocystidia).

Collection Examined – Jammu and Kashmir, Verinag (2300m), 33°30.113'N-074°10.123'E, growing solitary on leaf litter of *Pinus wallichiana* in coniferous forest, Nazir Ahmad Malik, PUN 9040, August 11th, 2015.

Edibility – Its edibility is unknown.

Distribution and Ecology – Peterson (2008) collected *Xerula kenya* first time from Kenya at an altitude of 923m on the litter of *Pinus radiata*. Presently, this Indian species has been collected growing on the litter of *Pinus wallichiana* at an elevation of 2300m during the month of August from Jammu and Kashmir.

Notes – Present collection falls under the section *Albotomentosae* of genus *Xerula* because of the presence of pileal hairs (setae) in the pileus cuticle as described by Petersen (2008). All the morphological details are matching with *Xerula kenya* R.H. Petersen as given by Petersen (2008). This collection was also compared with an allied species, *X. africana* (Dörfelt) R.H. Petersen which has sublimoniform basidiospores and bisterigmate basidia whereas the basidiospores are globose to ellipsoidal and the basidia are tetrasterigmate in *X. kenya* and in the present collection. This species is new record to India.

Xerula radicata* var. *setosa Malik N.A & Saini, M. K. var. nov.

Figs 12–17

Mycobank number: MB837996; Facesoffungi number: FoF09509

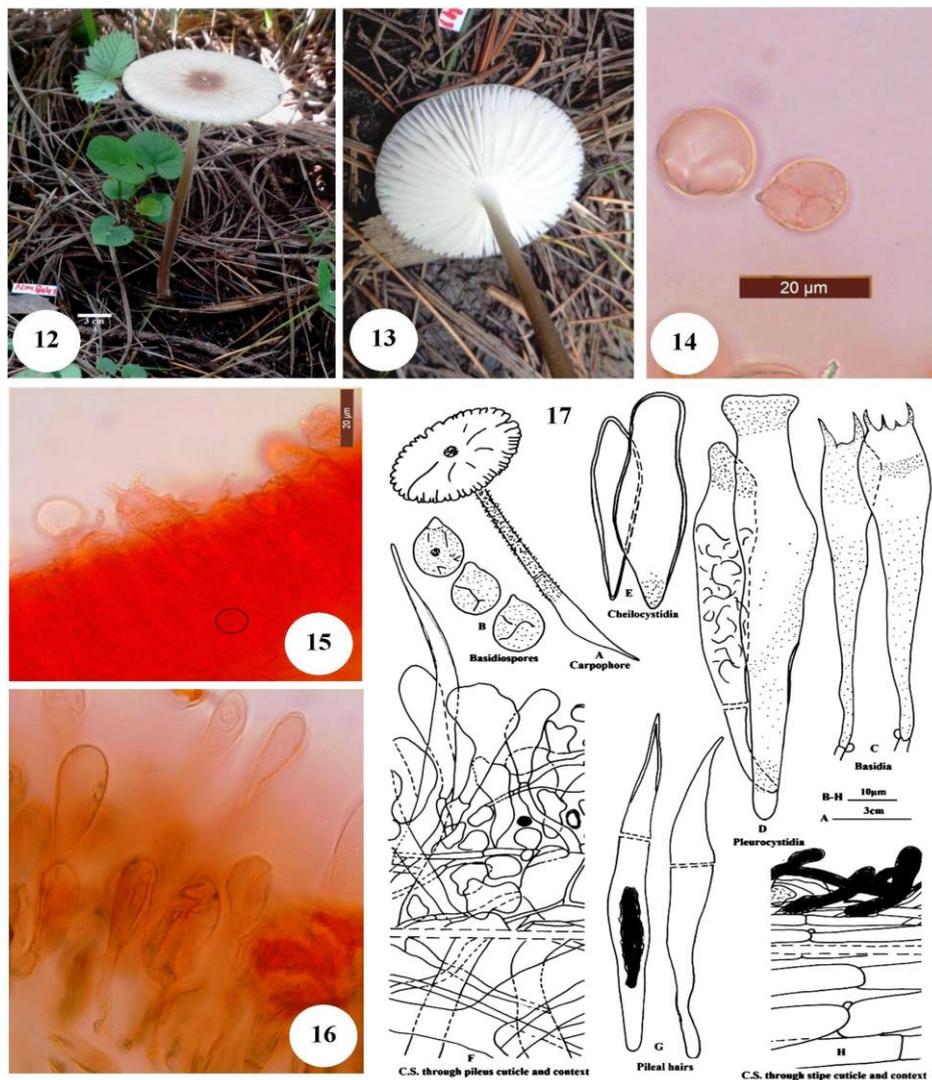
Etymology – The name of this variety is given on the basis of the presence of setae in the pileus cuticle.

Basidiocarp up to 12.0 cm in height. Pileus up to 5.5 cm broad, applanate; subumbonate; surface reddish grey (7B₂), greyish orange (6B₃) in the centre; moist; margin regular, striated; cuticle fully peeling; flesh up to 0.2 cm thick, white, unchanging; taste and odor mild. Pileal veil absent. Lamellae up to 0.5 cm broad, adnate to sub decurrent, crowded, equal, present in 3 to 4 tiers, off white with rarely white floccose edges, unchanging; lamellulae present; gill edges smooth. Stipe central, up to 11.5 cm long (excluding rooting base), up to 0.3 cm broad above, up to 0.5 cm broad in centre, up to 1.0 cm broad near base; obclavate, with 4.0 cm long rooting base; surface light brown (8B₃), off white near apex; white mycelium present at base; surface furfuraceous; scaly, scales pruinose to fibrillose, light brown (6D₄), white floccose near apex; hairy; solid; exannulate. Basidiospores 11.2–14.4 (17.6) × 9.6–12.8 (16.0) μm, Q = 1.1, globose to ellipsoidal, granular, rigid, single thick walled; inamyloid; apiculate, apiculus up to 0.83 long. Basidia 67.0–80.0 × 11.2–16.0 μm, clavate, clamp connections present at base, granular, bi to tetrasterigmate, commonly tetrasterigmate; sterigmata 3.2–6.4 μm long, hyaline to granular. Pleurocystidia 94.0–128.0 × 12.8–19.2 μm, clavate to utriform with blunt to truncated pronged apices, granular with yellowish content, protruding from basidial layer, abundant; cheilocystidia 40.0–64.0 × 11.0–14.4 μm, clavate to utriform, blunt tips, hyaline, partially double walled. Hymenophoral trama regular. Gill edge sterile. Pileus cuticle hyphal, ixocutis, made up of 1.6–2.4 μm broad, septate, hyaline hyphae, giving rise to clavate, sphaeropedunculate, pedicellate cells along with thick walled pileal hairs (setae), 120.0–128.0 × 8.0–11.2 μm, with tapering to narrowly pointed apices, with reddish brown content; context hyphal, made up of 6.4–19.2 μm broad, horizontally tangled, hyaline, septate hyphae. Stipe cuticle hyphal, made up of 2.4–6.4 μm broad, clavate to fusoid elements consisting yellowish content; caulocystidia absent; context hyphal, made up of 6.4–16.0 μm broad, longitudinally tangled, hyaline, septate, inflated hyphae. Clamp connections present.

Collection Examined – Jammu and Kashmir, Verinag (2300m), 33°30.113'N –074°10.123'E, growing solitary on leaf litter in coniferous forest, Nazir Ahmad Malik, PUN 9042, August, 11th 2015 (Holotype).

Edibility – Its edibility is unknown.

Notes – Present PUN 9042 falls under the section *Albotomentosae* of genus *Xerula* due to the presence of pileal hairs (setae) in the pileus cuticle as given by Petersen (2008). It matches well with the description of *Xerula radicata* (Relhan) Dörfelt of section *radicata* as given by Ronikier (2003) and Boekhout (1999) but differ from it due to the presence of pileal hairs and absence of caulocystidia in the present collection which are lacking in *X. radicata*, further the basidiospores are much larger $11.2\text{--}14.4$ (17.6) \times $9.6\text{--}12.8$ (16) μm in the presently examined collection instead of $13.0\text{--}16.0 \times 9.0\text{--}11.0$ as given for *X. radicata*. Thus, does not fit into any of the known varieties of *X. radicata* because according to Boekhout (1999) pileal hairs (setae) or cystidia are lacking in the variants of *X. radicata*. This collection was also compared with an allied species viz. *X. kenyae* R.H. Petersen in which basidiospores are globose to ellipsoidal without ridges and basidia are tertrastrigmate while present collection has bi to tetrasterigmate basidia and basidiospores are ridged. The present collection has applanate carpophore, subumbonate cap with striated margin, adnate to sub decurrent lamellae with white floccose edges, stipe has long rooting base up to 4.0 cm long, hairy, pileus cuticle with thick walled pileal hairs consisting reddish brown content, caulocystidia absent etc. From India *X. radicata* was earlier reported by Kumar et al. (2015) from Manipur. Present species is proposed as a new variant of *X. radicata* as *X. radicata* var. *seta* var. nov.

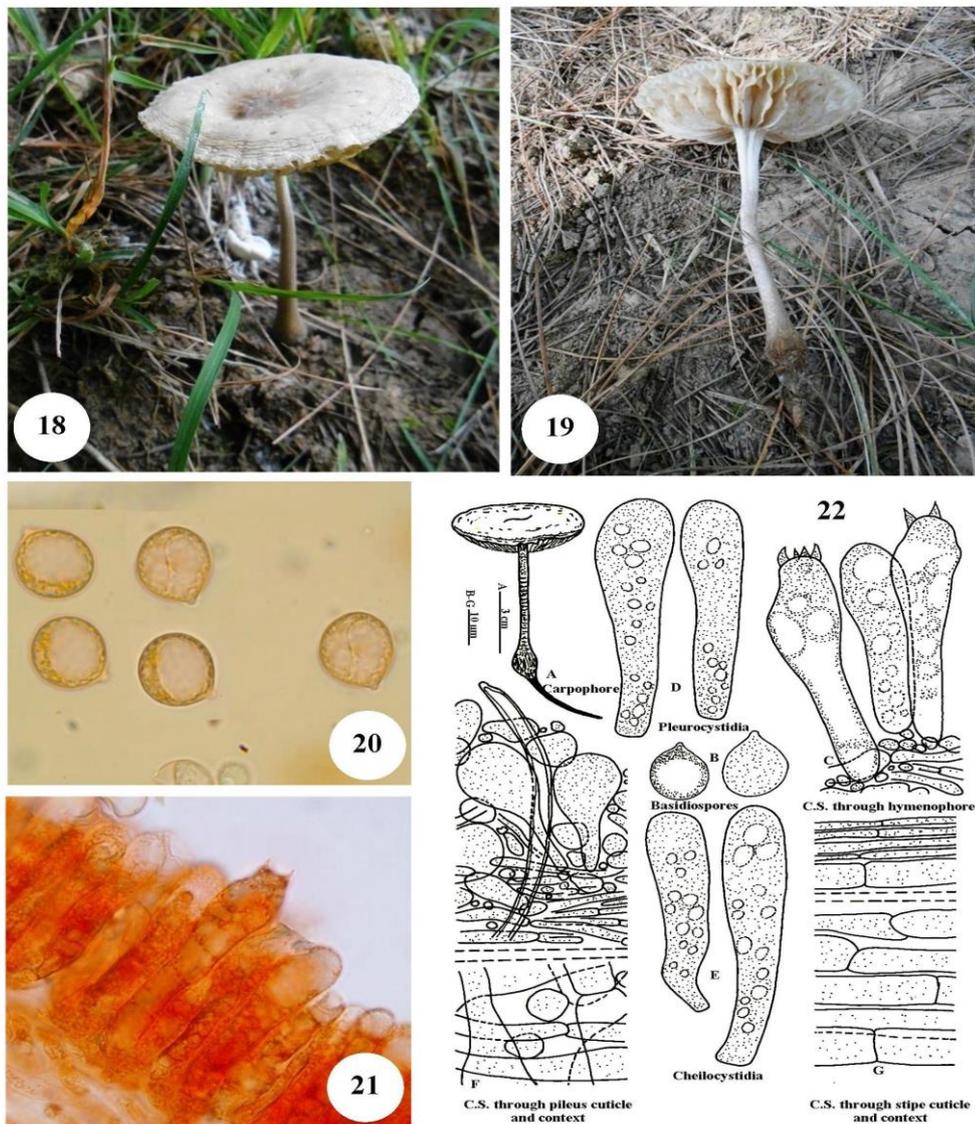


Figs 12–17 – *Xerula radicata* var. *setosa* var. nov. 12 Carpophore applanate with greyish orange centre and regular margin. 13 Underview of cap bearing white unchanging lamellae with smooth edges. 14 Microphotograph of basidiospore with ridges. 15 C.S. through hymenophore consisting

basidia with clamp connection near base. 16 C.S. through gelatinized pileus cuticle and context consisting turf of pilocystidia along with pileal hair. 17 Camera Lucida drawings (A Carpophore. B Basidiospores. C C.S. through hymenophore. D Pleurocystidia. E. Cheilocystidia F C.S. through pileus cuticle and context. G Pileal hairs. H C.S. through stipe cuticle and context).

Xerula furfuracea (Peck) Redhead, Ginns & Shoemaker, Mycotaxon 30: 362 (1987). Figs 18–22
 Mycobank number: MB133140; Facesoffungi number: FoF09510

Basidiocarp up to 9.0 cm in height. Pileus 5.0 cm broad; convex to applanate with a depressed centre; umbo absent; margin irregular; splitting at maturity; non-striate; radially wrinkled to puckered towards margins; surface yellowish grey (2B₂) with a darker brownish orange (6C₅) centre; dry; cuticle half peeling; flesh up to 0.2 cm thick, creamy white, unchanging; odor mild. Pileal veil absent. Lamellae broadly adnate to notched, subdistant, unequal, not in series, moderately broad (up to 0.5 cm), creamy white with pale orange (5A₃) shades, white powdery floccose depositions cover the lamellae, unchanging; gill edges serrate; lamellulae present. Stipe central, up to 8.0 cm long, up to 0.4 cm broad above, up to 0.8 cm broad at base, bulbous base with a long rooting base embedded in soil; surface yellowish white (4A₂) towards apex, brownish grey (6C₂) in the middle, light brown (6D₆) towards apex, unchanging; solid, scaly, scales floccose, white towards apex, furfuraceous towards middle and base; exannulate.



Figs 18–22 – *Xerula furfuracea*. 18 Carpophore growing solitary on humicolous soil. 19

Underview of cap and the stipe with a long rooting base. 20 Microphotograph showing globose to subglobose basidiospores. 21 C.S. through hymenophore showing bisterigmate basidia. 22 Camera Lucida drawings (A Carpophore. B Basidiospores. C C.S. through hymenophore. D Pleurocystidia. E. Cheilocystidia F C.S. through pileus cuticle and context. G C.S. through stipe cuticle and context).

Basidiospores 14.94–16.6 × 13.28–14.94 μm (excluding apiculus), Q = 1.1, globose to subglobose, smooth, granular, mostly granular towards periphery, inamyloid; apical pore absent; apiculate, apiculus 0.83–1.66 μm long, centric to excentric. Basidia 58.1–64.74 × 11.62–15.77 μm, claviform, granular, bisterigmate to tetrasterigmate; sterigmata 5.0–6.0 μm long, granular. Pleurocystidia 58.1–73.04 × 11.62–18.26 μm, claviform with rounded, blunt tips, granular, abundant. Cheilocystidia 53.12–68.0 × 10.0–14.11 μm, claviform with rounded, blunt apices, granular, abundant; gill edges heteromorphous. Hymenophoral trama regular. Pileus cuticle cellular, hymeniderm made up of 31.54–44.82 × 10.0–16.6 μm, pyriform to claviform cells intermixed with pileal hairs which are tapering to narrowly rounded, blunt apex, rarely inflated, thick double walled; context made up of 5.0–20.0 μm broad, septate, granular, hyphae intermixed with granular, cellular elements. Stipe cuticle hyphal, made up of longitudinally arranged, 2.5–5.0 μm broad, septate hyphae; caulocystidia absent; context hyphal, made up of 5.0–14.11 μm broad, septate, hyphae. Clamp connections absent throughout.

Collection Examined – Jammu and Kashmir, Baramulla, Khadgu Manglu (2150 m) 34° 23.706 N – 074°29.692 E, growing solitary on humicolous soil in coniferous forest, Naseema Aqbar Wani, PUN 9259, August 17th, 2015.

Distribution and Ecology – *Xerula furfuracea* was found growing solitary to gregarious from buried roots of hardwoods and on deciduous tree of *Acer saccharum* from Eastern North America by Redhead et al. (1987).

Notes – The morphoanatomical details of the presently examined collection matches well with the description provided for *Xerula furfuracea* (Peck) Redhead, Ginns & Shoemaker by Redhead et al. (1987). This species is characterized in possessing convex to applanate cap with a depressed centre, radially wrinkled to puckered margins, broadly adnate to notched lamellae and the stipe with a long rooting base embedded in soil covered with floccose to furfuraceous scales. The only difference being in the shape of basidiospores which are globose to subglobose in the present collection which otherwise are broadly ovoid to ellipsoid as reported by Redhead et al. (1987). This species is recorded for the first time from India.

Key to the investigated taxa

- 1 Carpophore small to medium sized; Basidiospores elliptical, guttulate, one guttule per spore; Pleurocystidia and Cheilocystidia fusoid ventricose; Pileus cuticle lacking setae or pileal hairs; Caulocystidia subulate with a broadened foot*Strobilurus tenacellus*
- 1' Carpophore large sized; Basidiospores globose to ellipsoidal, non-guttulate; Pleurocystidia and Cheilocystidia clavate to ventricose, utriform; Pileus cuticle with setae or pileal hairs; Caulocystidia clavate2
- 2 Stipe excentric; Gill edges smooth;*Xerula kenyae*
- 2' Stipe central; Gill edges smooth to serrate3
- 3 Carpophores growing on leaf litter; Cuticle fully peeling; Basidiospores globose to ellipsoidal; Gill edges sterile; Basidia with clamp connections at base; Clamp connections present at the stipe surface*X. radicata* var. *setosa* var. nov.
- 3' Carpophores growing on humicolous soil; Cuticle half peeling; Basidiospores globose to subglobose; Gill edges heteromorphous; Basidia without clamp connections at base; Clamp connections absent at the stipe surface*X. furfuracea*

Discussion

Mushrooms form the rich mycotic flora of Kashmir. Macrofungi selected from different areas of the study area belong to class Basidiomycetes. The present communication describes the general distribution, morphological description, macro and microscopic details of the four newly reported species of macrofungi viz. *Strobilurus tenacellus*, *Xerula kenyae*, *X. radicata* var. *setosa* var. nov. and *X. furfuracea* from the Indian subcontinent. These species were found growing solitary to scattered groups in the month of May and August at an altitude that ranges between 2150m-2750m. Among these species *Strobilurus tenacellus* releases a compound known as Strobilurin which suppresses the growth and development of the other fungi and its derivatives are also used as an important agricultural fungicide Tang et al. (2017).

Previous taxonomic studies on the genus *Strobilurus* focused largely on species from North America and Europe (Wells & Kempton 1971, Redhead 1980, Rexer & Kost 1989). From these two continents, a total of nine species have been reported with highest species diversity from North America. In East Asia, two species viz. *S. ohshimae* and *S. luchuensis* have been reported from Japan (Hongo 1955, Katumoto 2010, Terashima et al. 2016). A total of 13 species have been described till date with the addition of two species, *S. orientalis* and *S. pachycystidiatus* that have been reported from China (Qin et al. 2018). Some authors kept *Xerula* and *Oudemansiella* as two separate genera (Dörfelt 1979, Redhead et al. 1987, Petersen & Methven 1994, Contu 2000, Petersen & Baroni 2007, Petersen 2008). However, Dörfelt's work has greatly modified the genus *Xerula* by transferring sections viz. *Albotomentosae*, *Protoxerula* and *Radicatae* from *Oudemansiella* to *Xerula* and differentiated *Oudemansiella* with a rudimentary annulus as compared to exannulate stipe in case of genus *Xerula* (Dörfelt 1979, 1980, 1983, 1984). Based on the recent molecular phylogenetic analyses genus *Xerula* and *Oudemansiella* are placed in the *Physalacriaceae* clade (Moncalvo et al. 2002, Wilson & Desjardin 2005, Matheny et al. 2007). Genus *Oudemansiella* is differentiated from the *Xerula* in possessing crowded cheilocystidia with sterile lamellae edges and narrowly clavate basidioles in the hymenium as compared to fertile lamellae edges and subacrose basidioles in the hymenium in case of genus *Xerula* (Wang et al. 2008). Genus *Xerula* is represented by 15 species worldwide over Kirk et al. (2008) and Mycobank (2020) documents 99 species of this genus. However, from India 6 species of this genus have been reported so far (Sathe & Kulkarni 1980, Farook et al. 2013, Kumar et al. 2015). Macrofungi play an important ecological role because of their ectomycorrhizal and saprophytic nature, thereby are associated with health maintenance of the ecosystem. The diversity of these taxa remarkably contributes to the ecosystem replenishment and characterization of wild species growing in different localities of the North and South Kashmir from India.

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