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Diversity and Distribution Pattern of Mosses in Cold Desert of Leh, Ladakh

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ABSTRACT

Mosses form a prominent component of vegetation in the cold desert ecosystems and fairly influence cycling of nutrients, water and play important role in ecological constancy and resilience. They possess a large extent of phenotypic plasticity and photosynthetic efficiency, which allow them to adapt in cold regions. They provide a suitable habitat and food for many invertebrates in extreme environments. To understand such micro-ecosystems and processes, study of mosses is a prerequisite. Since inventory is a best method for developing a data base for characterization and conservation of biodiversity, we made extensive studies on the distribution and morphology of the mosses of Leh district in this Himalayan region. We recorded 30 species of mosses belonging to 21 genera and 11 families of mosses in Leh district of Ladakh region. Bryaceae were recorded with eight species followed by Mniaceae (5 sp.), Bartrameaceae (4 sp.), Amblystegiaceae and Leskeaceae (3 sp. each), Pottiaceae (2 sp.) and Pterobryaceae, Brachytheciaceae, Funariaceae, Grimmiaceae and Splachnaceae with one species each. At the generic level *Bryum* is recorded with six species followed by *Philonotis* (4 sp.), *Pohlia, Mnium, Cratoneuron* (2 sp. each) and *Anomobryum, Ptychostomum, Gemmabryum, Mniobryum, Mielichhoferia, Drepanocladus, Lescuraea, Haplocladium, Claopodium, Osterwaldiella, Anoectangium, Tortella, Brachythecium, Entosthodon, Racomitricum* and *Voitia* (one sp. each). Although the area is more prone to harsh environmental conditions such as stress due to dryness and cold (temperature <zero degree Celsius) the diversity of mosses is found to be high. Most of the species display turf growth form and high reproductive potential which is a strategy to survive in harsh environmental conditions.

Key words: *Bryophyta, Cold desert, Floristics, Mosses, Osterwaldiella, Peatl, Taxonomy*

INTRODUCTION

Bryophytes play an important role in ecosystem dynamics, nutrient cycling, providing microhabitats for other plants and animals, fills gaps in the habitats and promote plant succession (Batista, 2018; Oliveira, 2019). Many organisms such as blue green algae, protozoans, nematodes and insects are found to be associated with mosses for their shelter and food especially in extreme conditions (Acebey, 2003; Jiang *et al*., 2018,). The inventory of bryophyte species is highly significant in terms of micro-ecosystem functioning. The studies of plant communities and species diversity have gained importance as the biodiversity at global level is facing several challenges for its existence. Species diversity data is considered as foundation to biodiversity management and conservation and ecosystem functioning. There are some unique habitats for bryophytes in Ladakh regions, which harbor some distinctive species of mosses (Thoker *et al.,* 2019).

Bryophytes comprise about 20,000 species distributed all over the world (Goffinet and Shaw, 2009). Among the three phyla of Bryophytes (Marchantiophyta, Bryophyta, Anthocerophyta), the Bryophyta (mosses) is more diverse and abundant group. India harbors nearly 2500 species of bryophytes (Dandotiya *et al*., 2011). Mosses are found to exist in habitats such as rock surfaces, bark of trees, unconsolidated alluvium and moronic material on which other plants find difficulty in establishment and can survive in extreme environmental conditions (Govndapyari, 2014). Bryophytes can be highly specific to the particular environment factors such as temperature, light and water availability, substrate chemistry etc. making them good indicators for ecological conditions (Tiwari and Pant, 2002; Frego, 2007), pollution, climate change and tools for geological prospects (Zechmeister, 2019; Gignac, 2001). Bryophytes play a vital role as indicators of environmental pollution and can be employed in developing Index of Atmospheric Purity (IAP) (Dymytrova, 2009; Govindapyari *et al*., 2010).

Bryophytes have proved to be of some economic values as well (Glime and Saxena, 1990; Glime, 2007) such as medicines, packaging material, construction material, etc. Bryophytes with a wide range of scientific interest are excellent experimental material for studying many fundamental biological problems (Wood *et al*., 2000). The increasing variations of climate change through the various anthropogenic activities, as well as the agricultural and industrial development have led to the alteration of distribution patterns of bryophytes (Hernández-Hernández *et al*., 2019). There is a need to make a comprehensive report on the flora and the role of mosses in ecosystem functioning and subsequently for the conservation of these species. Ismail *et al*. (2020) recently updated a checklist of bryophytes of Jammu and Kashmir, and Narayan *et al.* (2001) studied bryophytes of Great Himalayan National Park (Kullu, Himachal Pradesh). However, the adjacent Union Territory of Ladakh remains still unexplored except a few studies (Dolma and Langer, 2012, 2013) on hepatic flora of Ladakh. In the present work, a survey has been undertaken to assess the moss diversity and distribution in Leh district of Ladakh region. The information on the diversity of mosses, their spatial heterogeneity, contribution in the community and their interactions with the ecosystem component is totally lacking (Jiang *et al*., 2018). Therefore, the taxonomic and distributional studies have become highly significant in ecosystem modelling and its use as resource material. In the dominion of the 'bryosphere' there are some unanswered questions, which need to be studied (Lindo and Gonzalez, 2010).

MATERIAL AND METHODS

Study area and study sites

Survey of the mosses was done in Leh district (32°-36°N, 75°-80°E) (Fig. 1) of Ladakh. It is a cold desert, located in the temperate region. It is characterized by high altitude, extreme aridity, coarse, porous and immature sandy soils and marked variations in diurnal and seasonal temperature (-27.9° to 34.8°). It has a short agriculture (cropping) seasons of 3-5 months and long freezing winters 5-7 months. The low rainfall (<100 mm per annum) and the relative humidity of around 40%-50% create the arid conditions.

The region comprises alpine mesophytic, oasitic and desert vegetation. Leh district is divided into nine blocks and the species were collected mainly from Kharu block, Leh block and Saspol block.

Sample collection

Collection of bryophytes were made from different areas like Igoo, Sakti, Gyamtsa, Nimmu and Saspol (Fig.1) in Leh district (Plate No. 1-3). Moss patches were peeled off with a knife or a chisel and collected from fields in polythene bags and paper envelopes and each population were kept separately. The plants were air dried thoroughly on blotting sheets. It takes around 3-5 days for the plant to dry. For the study of specimens, the plants were soaked in water in petri dishes. The different parts of the samples were taken out with the help of needles, brush and forceps. They were carefully observed under the binocular microscope (Magnus, MS13/MS24) and compound microscope (Olympus CX21FS1). The associated leafy liverworts, other mosses and algae were carefully separated (Bahuguna *et al*. 2015). Herbarium specimens were deposited at the Herbarium of the Department of Botany (DUH), University of Delhi and voucher numbers were issued by the incharge of the DUH herbarium. Mosses were duly identified with the help of various sources, available literature including e-floras, monographs and floras, Chopra (1975), Gangulee (1969-1980), Crum and Anderson (1981), Flora of North America Editorial Committee (2014). A systematic key and elaborated description with photographs and other important characters were prepared to form a base line data. In this paper text, order and families were arranged according to the classification of Goffinet and Shaw (2009).

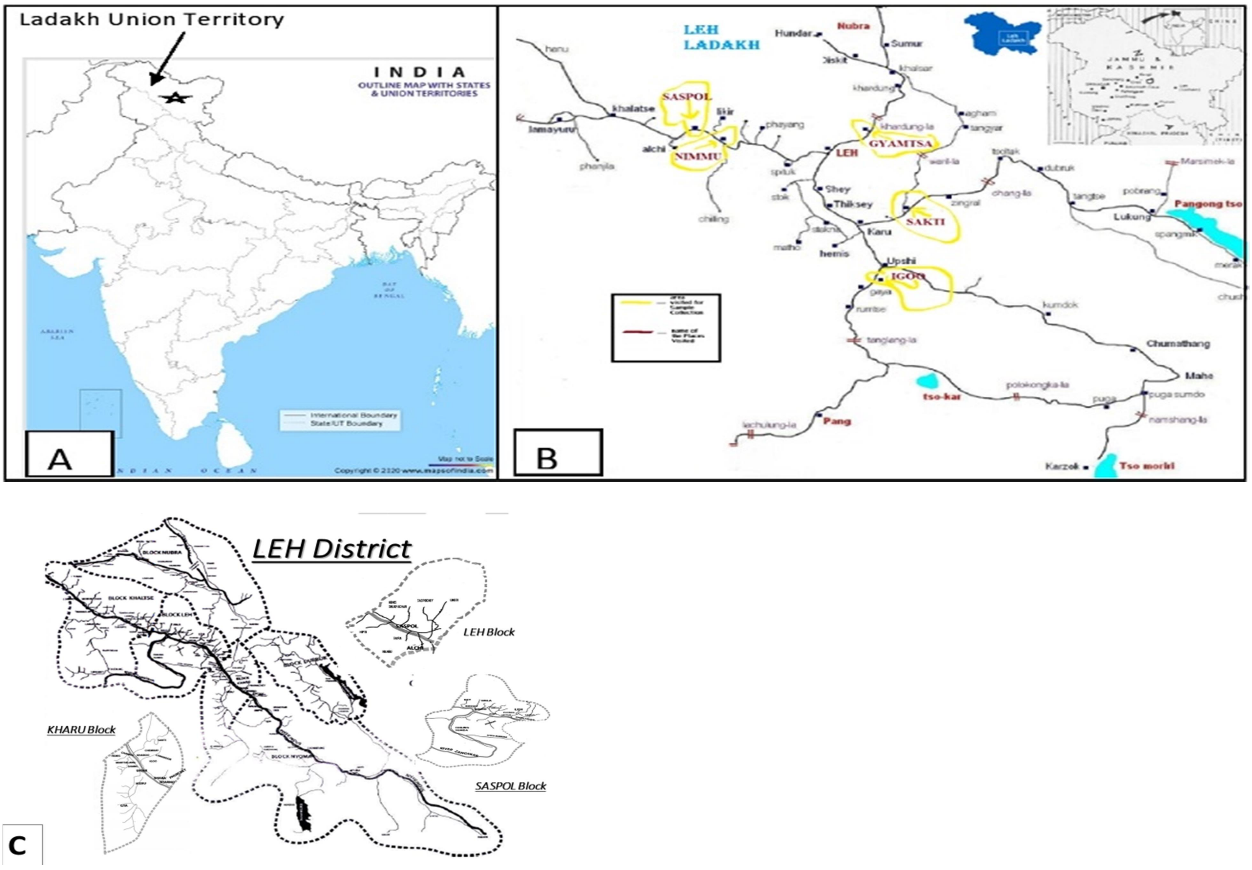

Fig. 1. (A) Map of India showing Union terrotory of Ladakh, Star indicates the location of Leh district; (B) Line map showing the various locations of plant collection. (C) Line map showing three blocks of leh district from where collections were made.

RESULT AND DISCUSSION

The study is based on more than 60 samples of 30 species of mosses collected during the field survey (2012) undertaken in various sites of Leh district. In the present study, we recorded 30 species in 21 genera and 11 families of mosses in Leh district of Ladakh. Bryaceae was found dominant family with eight species and five genera, *Bryum, Ptychostomum*, *Gemmabryum Anomobryum* and *Mniobryum.* Mniaceae were recorded with *Mnium*, *Pohlia* and *Mielichhoferia*. Bartrameaceae were reported with four species of *Philonotis,* Amblystegiaceae were recorded with *Cratoneuron* and *Drepanocladus.* Leskeaceae were represented by three species in three genera. Pottiaceae comprised two species each of *Anoectangium* and *Tortella.* Pterobryaceae, Brachytheciaceae, Funariaceae, Grimmiaceae and Splachnaceae were represented by one species each (Table 1, Fig. 2). Following is the description of the taxa studied.

Key to the Families		
1	Predominantly acrocarpous habit	go to… 2
	Predominantly pleurocarpous habit	go to… 8
2	a. Peristomeha plolepidous, leaves with strong costa; cells, thick walled, isodiametric, small, rounded, highly papillose. Peristome teeth 2-pronged.	Pottiaceae
	b. leaf cells smooth, rectangular, rhombic or polygonal. Peristome diplolepidous	go to… 3
3	a. Plants blackish green, occurring on exposed rocks. Leaves lanceolate, hair- pointed; cells small, parenchyamatous, often with undulating walls, Peristome teeth generally not 2-pronged, irregularly split or perforated, dorsal layer mostly thick, without cross-bars	Grimmiaceae
	b. Plant occurring on shaded soil.Leaf cells almost invariably smooth, isodiametric, more or less rhomboidal, or linear vermicular. Capsule, smooth	go to… 4
4	a. Plants delicate with rosette of leaves, lamina cells thin walled rectangular, smooth	Funariaceae
	b. Plants larger, leaf cells thick walled, rhombic or rounded or polygonal or rectangular papillose	go to… 5
5	a. Leaf cells smooth	go to… 6
	b. Leaf cells rectangular; mamillose, or ends of cells projected as mammillae, rarely smooth or papillose. Capsule spherical and usually furrowed	Bartramiaceae
6	Rhizoids with rough surface, papillose, clavate bodies present in the axils of upper leaves; stem section. pentagonal; stoma bounded by several cells; teeth united in pairs	Splachnaceae
	Rhizoids smooth	go to… 7
7	Lamina cells prosenchymatous, rhombic or rhomboidal to polygonal or linear and vermiform; basal cells quadrate or rectangular.	Bryaceae
	All cells of the leaf alike, usually parenchymatous, rounded to polygonal, often in oblique rows from the nerve	Mniaceae
8	Pleurocarpous mosses, leaf cells prosenchymatus, smooth, basal leaf cells thin smooth, Alar cells absent or indistinct	Pterobryaceae
	Leaves of stem and branch slightly different, Leaf cells usually isodiametric, small and papillose; alar cells slightly differentiated	Leskeaceae
	or elongate, prosenchymatous and smooth	go to… 9
9	Alar cells distinct, Central strand poorly differentiated or absent, lamina cells linear, cost ending below the apex of lamina.	Amblystegiaceae
	Alar cells absent, Central strand well-developed, lamina cell narrow rhombic, costa covering one-third of lamina	Brachytheciaceae

Table 1. List of recorded species of mosses with their habitat, growth form, and site of collection.

Family and Scientific name and herbarium Number	Growth form/ habitat	Locality/ altitude(m)amsl	Figure Number
Funariaceae			
(1)*Entosthodon wallichii* Mitt. DUH 14697	Turf, on wet soil and rocks	Igoo:3300m (33.8325°N,77.8650°E) [KHARU BLOCK]	Plate-1, Figs:1(a-e)
Grimmiaceae			
(2) *Racomitrium fuscescens* Wilson DUH 14698	Cushion, on dry exposed rocks	Nimmu: 3140m (34.1952°N,77.335°E) [LEH BLOCK]	Plate-1, Figs: 2(a-e)
Pottiaceae			
(3) *Anoectangium thomsonii* Mitt. DUH 14699	Turf, on wet rocks	Gyamtsa: 3524m (34.169°N,77.579°E) [LEH BLOCK]	Plate-1,Figs: 3(a-e)
(4) *Tortella fragilis* (Hook. et Wilson.) Limpr. DUH 14700	Turf, on exposed rocks	Nimmu: 3140m, (34.1952°N,77.335°E) [LEH BLOCK] Saspol: 4145m (34.3519°N,77.1703°E) [SASPOL BLOCK]	Plate-1,Figs: 4(a-e)
Splachnaceae			
(5)*Voitia nivalis* Hornsch. DUH 14701	Open turf on soil (horse dung)	Nimmu: 3140m (34.1952°N,77.3353°E) [LEH BLOCK]	Plate-1,Figs: 5(a-e)
Bryaceae			
(6) *Anomobryum polymorphum* Dix. DUH 14702	Turf on wet rocks	Nimmu: 3140m, (34.1952°N,77.3353°E) [LEH BLOCK] Saspol: 4145m (34.3519°N,77.1703°E) [SASPOL BLOCK]	Plate-1,Figs: 6(a-e)
(7) *Bryum atrovirens* Brid. DUH 14703	Turf on wet soil	Gyamtsa: 3524m (34.169°N,77.579°E) [LEH BLOCK]	Plate-1,Figs: 7(a-e)
(8)*Bryum cellulare* Hook. DUH 14704	Turf on wet soil	Nimmu: 3140m, (34.1952°N,77.3353°E) [LEH BLOCK] Saspol: 4145m (34.3519°N,77.1703°E) [SASPOL BLOCK]Igoo: 3300m (33.8325°N,77.8650°E) [KHARU BLOCK]	Plate-1,Figs: 8(a-e)
(9)*Bryum pseudotri quetrum* (Hedw.) P. Gaertn., B. Mey. & Scherb. DUH 14705	Turf on wet soil	Nimmu: 3140m (34.1952°N,77.3353°E) [LEH BLOCK] Saspol: 4145m (34.3519°N,77.1703°E) [SASPOL BLOCK] Sakti: 3812m (33.9978°N,77.8167°E) [LEH BLOCK]	Plate-1,Figs: 9(a-e)

(10) *Bryumre curvulum* Mitt. DUH 14706	Turf on wet soil	Igoo: 3300m (33.8325°N,77.8650°E) [KHARU BLOCK]	Plate-1,Figs: 10(a-e)
(11) *Gemmabryuma piculatum* (Schewägr.) J.R. Spence &H.P. Ramsay DUH 14707	Turf on wet soil	Nimmu: 3140m, (34.1952°N,77.3353°E) [LEH BLOCK] Saspol: 4145m (34.3519°N,77.1703°E) [SASPOL BLOCK]	Plate-2, Figs: 1(a-e)
(12) *Mniobryum wahlenbergii* (F. Weber & D. Mohr) Jenn. DUH 14708	Turf on wet soil	Igoo: 3300m (33.8325°N,77.8650°E) [KHARU BLOCK]	Plate-2,Figs: 2(a-e)
(13) *Ptychostomum capillare* (Hedw.) D. T. Holyoak & N. Pedersen DUH 14709	Turf on wet soil	Nimmu: 3140m, (34.1952°N,77.3353°E) [LEH BLOCK] Saspol: 4145m (34.3519°N,77.1703°E) [SASPOL BLOCK]	Plate-2,Figs: 3(a-e)
Mniaceae			
(14)*Mielichhoferia mielichho feriana* (Funck) Loeske DUH 14680	Turf on wet soil	Igoo: 3300m (33.8325°N,77.8650°E) [KHARU BLOCK]	Plate-2,Figs: 4(a-e)
(15) *Mnium spinulosum* Bruch & Schimp. DUH 14681	Mat on wet soil	Nimmu: 3140m, (34.1952°N,77.3353°E) [LEH BLOCK] Saspol: 4145m (34.3519°N,77.1703°E) [SASPOL BLOCK]	Plate-2, Figs: 5(a-e)
(16) *Mnium thomsonii* Schimp. DUH 14682	Mat on wet soil	Nimmu: 3140m, (34.1952°N,77.3353°E) [LEH BLOCK] Saspol: 4145m (34.3519°N,77.1703°E) [SASPOL BLOCK]	Plate-2, Figs: 6(a-d)
(17) *Pohlia camptotrachela* (Ren.& Card.) Broth. DUH 14683	Turf on wet soil	Nimmu: 3140m (34.1952°N,77.3353°E) [LEH BLOCK]	Plate-2, Figs: 7(a-e)
(18) *Pohlia cruda* (Hedw.) Lindb. DUH 14684	Turf on wet soil	Igoo: 3300m (33.8325°N,77.8650°E) [KHARU BLOCK]	Plate-2, Figs: 8(a-e)
Bartramiaceae			
(19) *Philonotis falcata* (Hook.) Mitt.; DUH 14685	Turf on wet rocks	Nimmu: 3140m (34.1952°N,77.3353°E) [LEH BLOCK] Saspol: 4145m (34.3519°N,77.1703°E) [SASPOL BLOCK] Sakti: 3812m (33.9978°N,77.8167°E) [LEH BLOCK]	Plate-2, Figs: 9(a-e)

(20) *Philonotis fontana* (Hedw.) Brid.; DUH 14686	Turf on wet soil	Sakti: 3812m (33.9978°N,77.8167°E) [LEH BLOCK]	Plate-2, Figs: 10(a-e)
(21) *Philonotis mollis* (Doz. & Molk.) Mitt. DUH 14687	Turf on wet soil	Nimmu: 3140m (34.1952°N,77.3353°E) [LEH BLOCK] Saspol: 4145m (34.3519°N,77.1703°E) [SASPOL BLOCK]	Plate-3, Figs: 1(a-e)
(22) *Philonotis seriata*Mitt.; DUH 14688	Turf on wet soil	Nimmu: 3140m (34.1952°N,77.3353°E) [LEH BLOCK]	Plate-3, Figs: 2(a-e)
Amblystegiaceae			
(23) *Cratoneuron commutatum* (Hedw.) G. Roth DUH 14689	Mat in marshes	Igoo: 3300m (33.8325°N,77.8650°E) [KHARU BLOCK]	Plate-3, Figs: 3(a-e)
(24) *Cratoneuronfilicinum* (Hedw.) Spruce DUH 14690	Mat in marshes	Nimmu: 3140m (34.1952°N,77.3353°E) [LEH BLOCK] Saspol: 4145m (34.3519°N,77.1703°E) [SASPOL BLOCK]	Plate-3, Figs: 4(a-e)
(25) *Drepanocladusex annulatus* (Schimp.) Warnst. DUH 14691	Mat in marshes	Nimmu: 3140m (34.1952°N,77.3353°E) [LEH BLOCK] Sakti: 3812m (33.9978°N,77.8167°E) [LEH BLOCK]	Plate-3, Figs: 5(a-e)
Leskeaceae			
(26) *Claopodium assurgens* (Sull. & Lesq.) Card. DUH 14692	Mat in marshes	Nimmu: 3140m (34.1952°N,77.3353°E) [LEH BLOCK]	Plate-3, Figs: 6(a-e)
(27)*Haplocladium microphyllum* (Hedw.) Broth. DUH 14693	Mat in marshes	Nimmu: 3140m (34.1952°N,77.3353°E) [LEH BLOCK]	Plate-3, Figs: 7(a-e)
(28) *Lescuraeain curvata* (Hedw.) E. Law-ton DUH 14694	Mat on shaded rocks	Gyamtsa: 3524m (34.169°N,77.579°E) [LEH BLOCK]	Plate-3, Figs: 8(a-e)
Brachytheciaceae			
(29) *Brachythecium rivulare* Schimp; DUH 14695	Mat on shaded rocks	Nimmu: 3140m (34.1952°N,77.3353°E) [LEH BLOCK]	Plate-3, Figs: 9(a-e)
Pterobryaceae			
(30) *Osterwaldiella monosticta* M. Fleisch. Ex Broth. DUH 14696	Mat on shaded rocks	Igoo: 3300m (33.8325°N,77.8650°E) [KHARU BLOCK]	Plate-3, Figs: 10(a-e)

Table 2. Site wise species list and the number of species found at each site.

S. No	LEH BLOCK			KHARU BLOCK	SASPOL BLOCK
	NIMMU 3140m (34.1952°N,77.3353°E)	**GYAMTSA 3524m (34.169°N,77.579°E)**	**SAKTI 3812m (33.9978°N,77.8167°E)**	**IGOO 3300m (33.8325°N,77.8650°E)**	**SASPOL 4145m (34.3519°N,77.1703°E)**
01.	*Racomitrium fuscescens* Wilson DUH 14698	*Anoectangium thomsonii* Mitt. DUH 14699	*Bryum pseudotri-quetrum* (Hedw.) P. Gaertn., B. Mey. & Scherb. DUH 14705	*Entosthodon-wallichii* Mitt. DUH 14697	*Tortella fragilis* (Hook. et Wilson.) Limpr. DUH 14700
02.	*Tortella fragilis* (Hook. et Wilson.) Limpr. DUH 14700	*Bryum atrovirens* Brid. DUH 14703	*Philonotis falcata* (Hook.) Mitt.; DUH 14685	*Bryum cellula-re* Hook. DUH 14704	*Anomobryum pol-ymorphum* Dix. DUH 14702
03.	*Voitia nivalis* Hornsch. DUH 14701	*Lescuraea incurvata* (Hedw.) E. Lawton DUH 14694	*Philonotis fon-tana*(Hedw.) Brid.; DUH 14686	*Bryum recur-vulum*Mitt. DUH 14706	*Bryum cellulare* Hook. DUH 14704
04.	*Anomobryum pol-ymorphum* Dix. DUH 14702		*Drepanocladus exannu-latus* (Schimp.) Warnst. DUH 14691	*Mniobryum wahlenbergii* (F.Weber &D.Mohr) Jenn. DUH 14708	*Bryumpseudotri-quetrum* (Hedw.) P. Gaertn., B. Mey. &Scherb. DUH 14705
05.	*Bryum cellulare* Hook. DUH 14704			*Mielichhoferia mielichhoferi-ana* (Funck) Loeske DUH 14680	<u>*Gemmabryum apiculatum*</u> (Schewägr.) J.R. Spence &H.P. Ram-say DUH 14707
06.	*Bryump seudotri-quetrum* (Hedw.) P. Gaertn., B. Mey. &Scherb. DUH 14705			*Pohliacruda* (Hedw.) Lindb. DUH 14684	*Ptychosto-mum capillare* (Hed w.) D. T. Holyoak & N. Pedersen DUH 14709
07.	<u>*Gem-mabryumapicula-tum*</u> (Schewägr.) J.R. Spence &H.P. Ramsay DUH 14707			*Cratoneuron commutatum* (Hedw.) G. Roth DUH 14689	*Mnium spinulosum* Bruch & Schimp. DUH 14681
08.	*Ptychosto-mum capillare* (He dw.) D. T. Holy-oak& N. Pedersen DUH 14709			*Osterwaldiella monosticta*M. Fleisch. Ex Broth. DUH 14696	*Mnium thomsonii* Schimp. DUH 14682

09.	*Mnium spinulosum* Bruch & Schimp. DUH 14681				*Mnium thomsonii* Schimp. DUH 14682
10.	*Mnium thomsonii* Schimp. DUH 14682				*Philonotis falcata* (Hook.) Mitt.; DUH 14685
11.	*Mnium thomsoni-i*Schimp. DUH 14682				*Philonotismollis* (Doz. &Molk.) Mitt. DUH 14687
12.	*Pohlia camptotra-chela* (Ren.& Card.) Broth. DUH 14683				*Cratoneuronfilici-num* (Hedw.) Spruce DUH 14690
13.	*Philonotis falcata* (Hook.) Mitt.; DUH 14685				
14.	*Philonotis mollis* (Doz. & Molk.) Mitt. DUH 14687				
15.	*Philonotis seriata* Mitt.; DUH 14688				
16.	*Cratoneuron filici-num* (Hedw.) Spruce DUH 14690				
17.	*Drepanocladus exannulatus* (Schimp.) Warnst. DUH 14691				
18.	*Claopodium assur-gens* (Sull. & Lesq.) Card. DUH 14692				
19.	*Haplocladium mi-crophyllum* (Hedw.) Broth. DUH 14693				
20.	*Brachytheciu mriv-ulare* Schimp; DUH 14695				

A comprehensive understanding of species diversity and its spatial patterns is important for planning of conservation strategy which provides a way for exploration of the relationships between organisms and their environments (Jiang *et al.,* 2018). The present study site is characterized by the very low rainfall and humidity and extreme fluctuation of diurnal temperature. The mosses in such conditions exhibit many unique morphological and ecological adaptations which help them to survive. The individuals remain in large groups, form the tuft or cushion growth forms. They accumulate a combination of special sugars and sugar alcohols concentrated in their cells to prevent the freezing of cellular water (Lu *et al*., 2019).

Species diversity

Thoker and Patel (2019) and Ismail *et al.* (2020) recorded the bryophytes of Jammu and Kashmir only and Dolma and Langer (2012, 2013) studied the *Riccia* species for Ladakh region, however, the information on the mosses of Ladakh region is totally lacking. At the generic level *Bryum* and *Philonotis* with four species of each were found to be dominant genera (Fig. 2). *Pohlia, Mnium* and *Cratoneuron* were represented by two species each. *Anomobryum, Ptychostomum*, *Gemmabryum, Mniobryum, Mielichhoferia, Drepanocladus, Lescuraea, Haplocladium, Claopodium, Osterwaldiella, Anoectangium, Tortella, Brachythecium, Entosthodon, Racomitricum, Voitia* are represented by one species each.

Growth forms

Most of the species of the present study shows turf growth form including species such as *Endosthodon walichii, Ptychostomum capillare, Bryum cellulare, Bryum atrovirens, Anomobryum polymorphum*. Some species such as *Bryum pseudo- triquetrum* represented robust turf, *Mniobryum walenberghii* shows lax turf and *Mielichhoferia mielichhoferi* shows dense turf. *Mielichoferia* occurs on sites of other metallic rocks. *Philonotis fontana* recorded in marshy sites. *Anoectangium* and *Philonotis* were recorded in calcium rich wet rocks. *Bryum pseudotriquetrum* mainly found in specific-coloured rocks life forms. The predominant growth form was the turf (19 species) followed by the mat (10 species) and cushion (1 species). The results were analyzed on the basis of relationship between the adaptive strategy and growth form of mosses according to Glime (2017). The mat forms dominated in the hygric sites, whereas turf and cushion forms were mainly recorded in xeric habitats. The marshy areas, a characteristic of Ladakh provides many microhabitats for bryophytes.

Habitat specificity and adaptability

Bryum cellulare, Drepanocladus ex annulatus, Cratoneuron filicum, Ptychostomum capillare, Philonotis seriata, Philonotis falcata were frequently encountered species in large patches, which were found in almost all the sites, showing their adaptability to heterogeneous habitats. *Osterwaldiell amonosticta* and *Racomitricum fuscescens* are endemic to this area, which are detected as rare species (found only once) with specific specificity of habitat. Jiang *et al*. (2018) reported that the diversity patterns and community structure of bryophytes alters in response to environmental gradients. They also reported unique occurrence of some species in the sample units with high habitat specificity and species association. *Drepanocladus ex annulatus, Cratoneuron filicum* and *C. commutatum* were always recorded in the marshy areas floating in somewhat acidic water (pH 4.8) water along with grasses. *Entosthodon wallichii* and *Voitia nivalis*were always found growing on the cattle dung indicating the habitat specificity. *Bryum cellulare, Bryum pseudo- triquetrum* and *Philonotis falcata* were found widely distributed especially in the calcium rich wet rocks. All the species of *Philonotis* were found in calcium rich substrata.

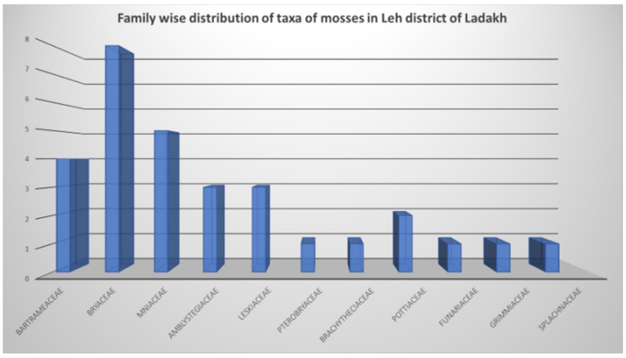

Fig. 2. Family wise distribution of taxa of mosses in Leh district of Ladakh.

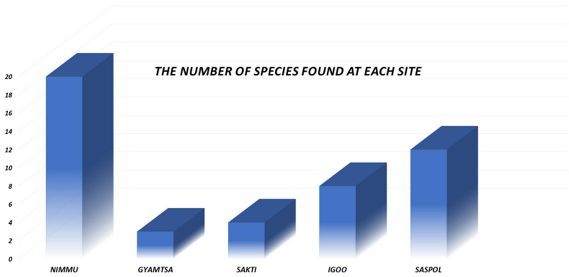

Fig. 3. The number of species found at eachsite

CONCLUSION

During present study we recorded 30 species of mosses, of which some show a high habitat specificity (*Drepanocladus ex annulatus, Cratoneuron filicum, C. commutatum,Voitia nivalis)* and adaptability (*Bryum* and *Philonotis*, *Tortella* species). These taxa seem to have some key features that allow them to survive in severe cold regions, including morphological plasticity. Most species show turf growth form, which is a strategy to protect the young individuals on inner side. The data on diversity patterns and species composition and association of bryophytes will help in planning and management conservation strategies at functional biotic-group levels.

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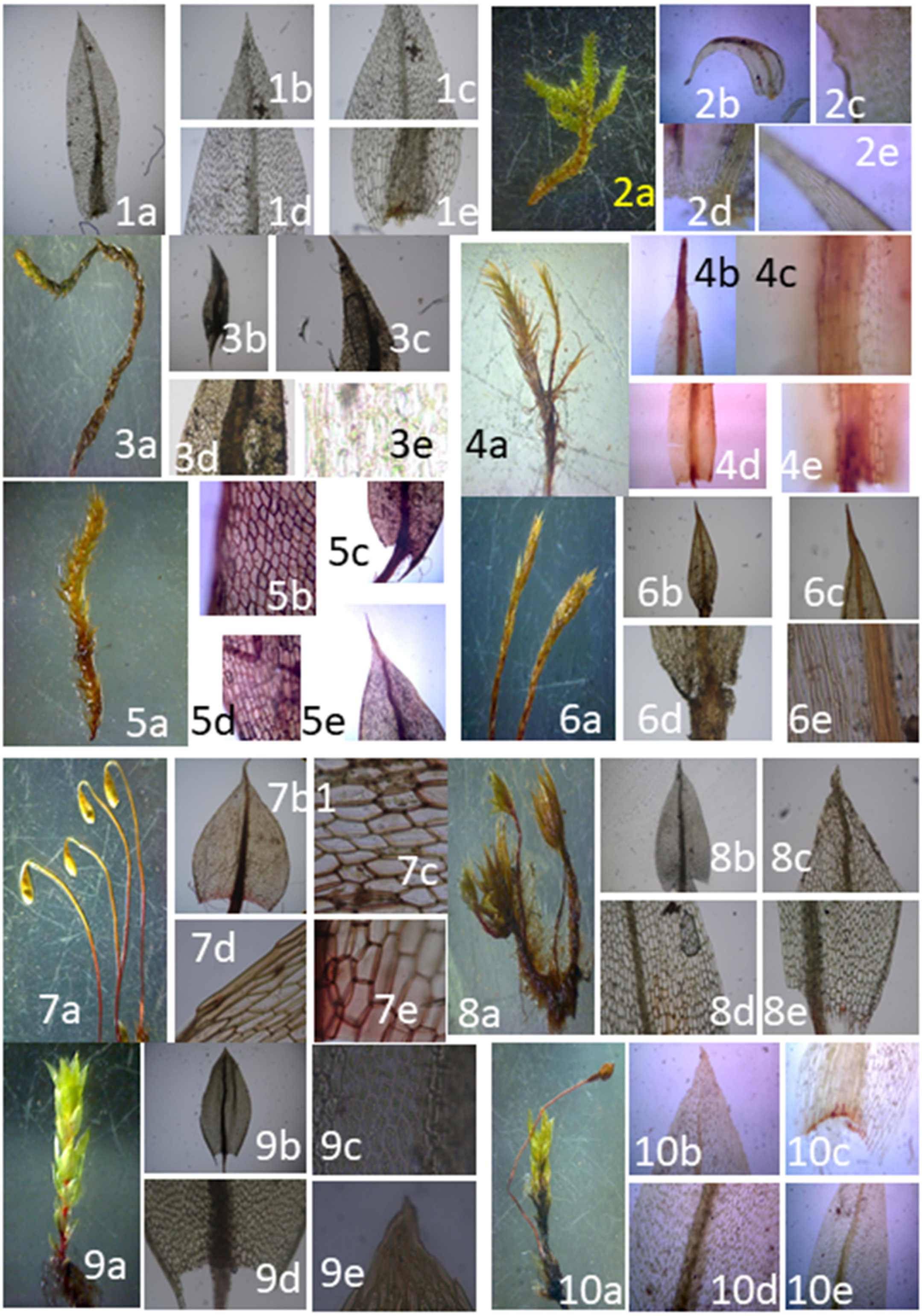
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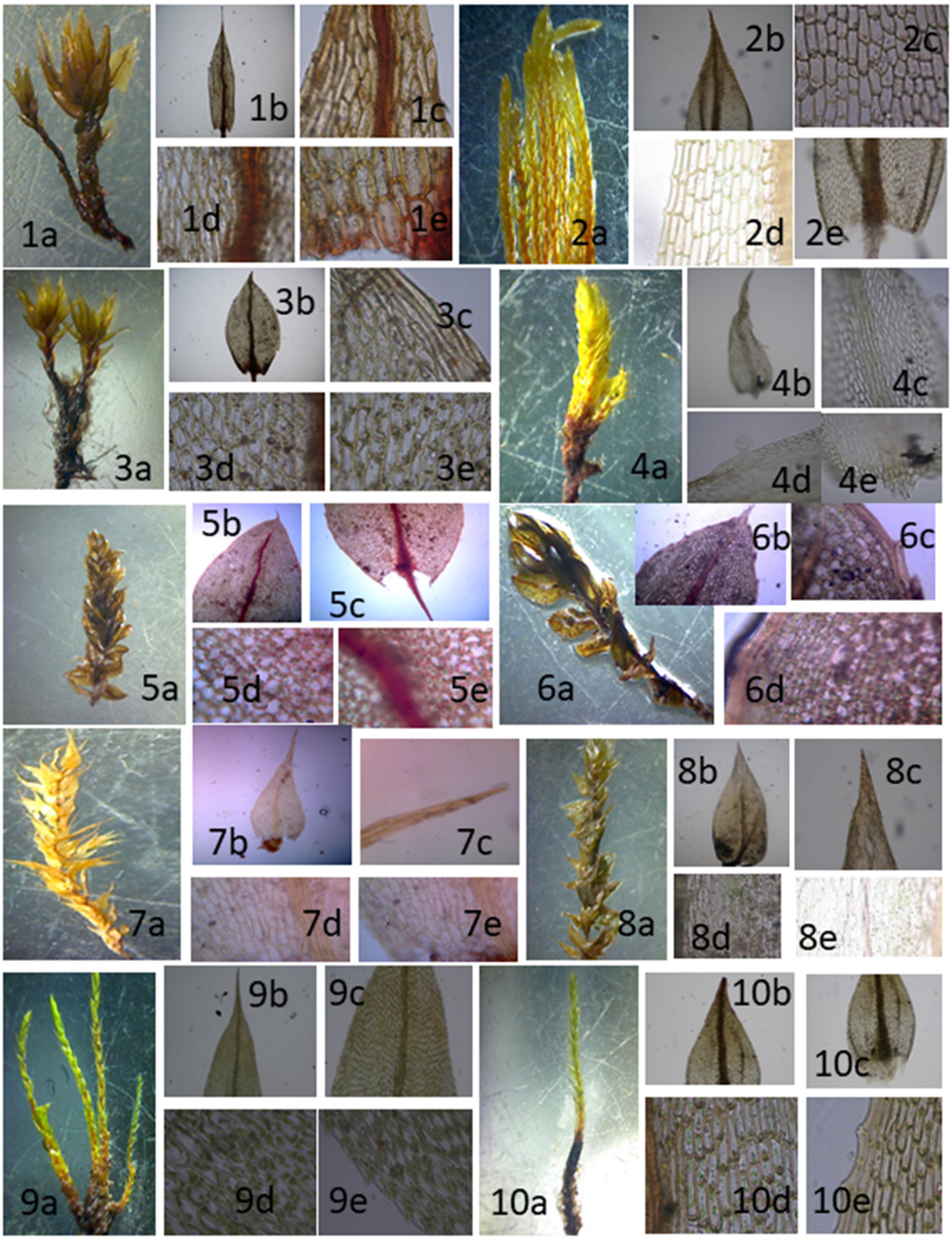
PLATE-1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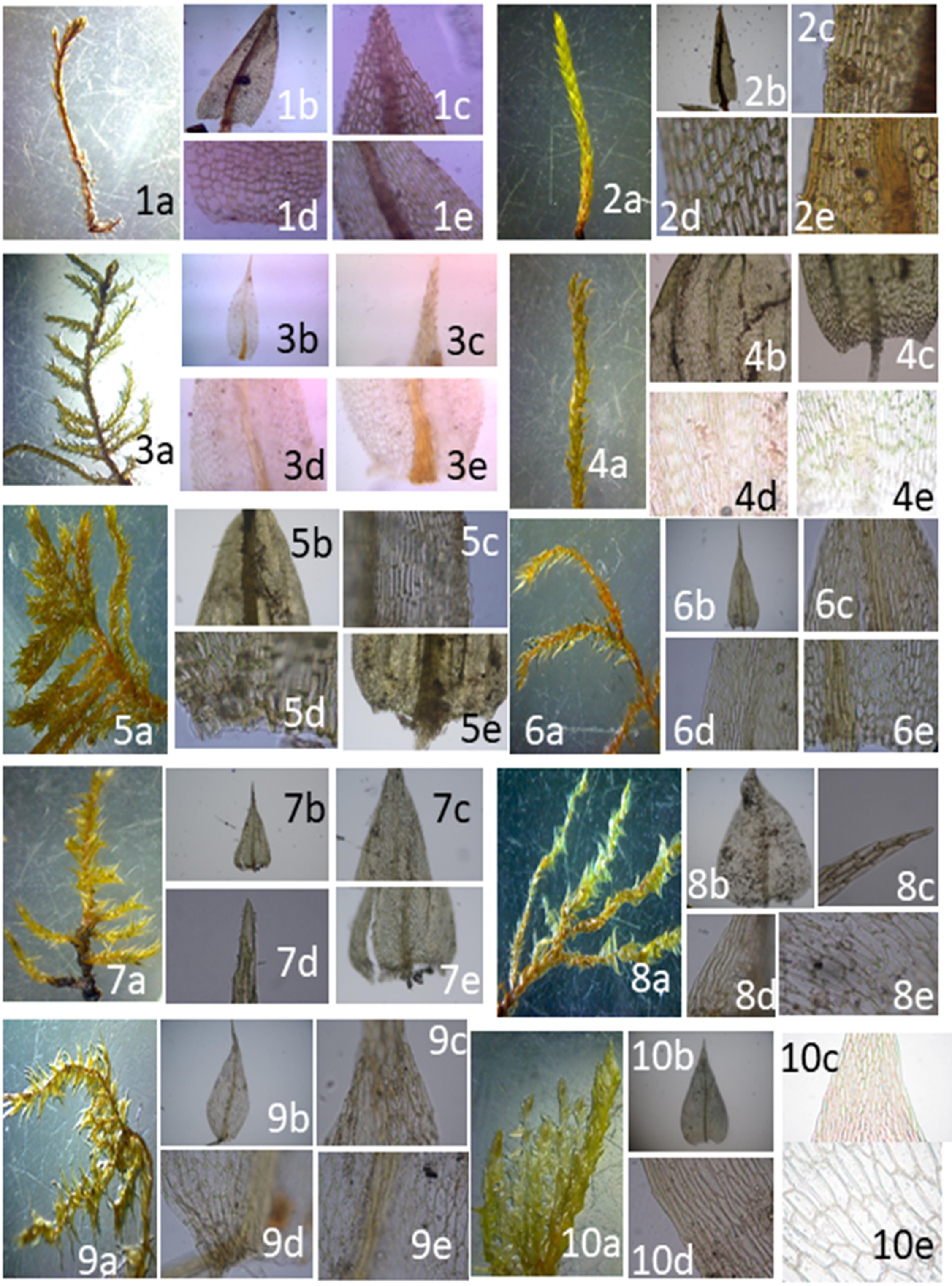
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PLATE-3

PLATE-1

Figures: 1(a-e): ***Entosthodonwalichii,*** (1a)Leaf whole mount, (1b) leaf tip, (1c) Leaf apex, (1d) Leaf mid potion, (1e) Leaf basal cells.

Figures: 2(a-d): ***Racomitriumfuscescens,*** (2a) Morphology, (2b) Leaf whole mount, (2c) Leaf cells, (2d), Basal cells and leaf tip cells with narrow lumens and sinuose walls.

Figures: 3(a-e): ***Anoectangiumthomsonii,*** (3a) Morphology, (3b) Leaf whole mount, (3c) Leaf cells, (3d) Leaf marginal cells, (3e) Leaf basal portion.

Figures: 4(a-d):***Tortella fragilis,*** (4a) Morphology, (4b) Leaf apex, (4c) leaf mid portion cells, (4d) Leaf basal portion.

Figures: 5(a-e): ***Voittia nivalis:*** (5a) Morphology, (5b) Leaf mid portion cells, (5c) Leaf basal portion, (5d) Leaf basal cells, (5e) Leaf apex.

Figures: 6(a-e):***Anomobryumpolymorphum,*** (6a) Morphology, (6b) Leaf whole mount, (6c) Leaf tip, (6d) Basal leaf cells, (6e) Mid leaf cells.

Figures: 7(a-e):***Bryum atrovirens,*** (7a) Morphology, (7b) Leaf whole mount, (7c) Mid portion leaf cells, (7d) Marginal leaf cells, (7e) Basal cells.

Figures: 8(a-e): ***Bryumcellulare,*** (8a) Morphology, (8b) Leaf whole mount, (8c) Leaf tip cells, (8d) Leaf cells mid portion, (8e) Leaf basal cells.

Figures: 9(a-e):***Bryumpseudotriquetrum,*** (9a) Morphology, (9b) Leaf whole mount, (9c) Mid portion cells, (9d) Basal leaf cells, (9e) Leaf tip cells.

Figures: 10(a-e): ***Bryumrecurvulum,*** (10a) Morphology, (10b) Apical leaf cells, (10c) Basal leaf cells, (10d) Mid leaf cells, (10e) Leaf cells.

PLATE-2

Figures: 1(a-e): ***Gemmabryumapiculatum,***(1a) Morphology, (1b) Apical leaf cells, (1c) Mid-leaf cells, (1d) apical Laminal cells, (1e) Basal leaf cells.

Figures: 2(a-e): ***Mniobryumwahlenberghii,*** (2a) Morphology, (2b) Leaf apical portion, (2c) Laminal cells, (2d) Leaf marginal cells, (2e) Leaf basal portion.

Figures: 3(a-e):***Ptychostomumcapillare,*** (3a) Morphology, (3b) Leaf W.M, (3c) Apical leaf cells, (3d) Mid leaf cells, (3e) Basal cells.

Figures: 4(a-e): ***Mielichhoferiamielichhoferiana,*** (4a) Morphology, (4b) Leaf whole mount, (4c) Leaf tip, (4d) Leaf mid portion, (4e) Leaf cells.

Figures: 5(a-e): ***Mnium spinolusum,*** (5a) Morphology, (5b) Leaf with red costa, (5c) Leaf base, (5d) Leaf cells, (5e) Leaf costa.

Figures: 6(a-d): ***Mnium thomsonii,*** (6a) Morphology, (6b) Leaf tip cells, (6c) Marginal leaf cells with sharp teeth, (6d) Ovate hexagonal leaf cells.

Figures: 7(a-e): ***Pohliacamptotrachlea,*** (7a) Morphology, (7b) Leaf whole mount, (7c) Leaf tip, (7d) Leaf cells mid portion, (7e) Basal leaf cells.

Figures: 8(a-e): ***Pohliacruda,*** (8a)Morphology, (8b) Leaf whole mount, (8c) Leaf tip, (8d, 8e) Leaf cells.

Figures: 9(a-e): ***Philonotis falcata,*** (9a) Plant morpholgy, (9b) Leaf tip, (9c) Mammilose leaf cells, (9d) Leaf cells, (9e) Marginal denticulate leaf cells.

Figures: 10(a-e): ***Philonotisfontana,*** (10a) Plant morphology, (10b) Leaf apex, (10c) leaf basal cells, (10d) Mid portion leaf cells, (10e) Leaf marginal cells

PLATE -3

Figures: 1(a-e): ***Philonotismollis,***(1a) Morphology, (1b) Leaf whole mount, (1c) Leaf apex, (1d) Leaf basal cells, (1e) Leaf margins.

Figures: 2(a-e): ***Philonotisseriata***(2a) Morphology, (2b) Leaf whole mount, (2c) Leaf cells, (2d) Basal cells, (2e) Apical leaf cells.

Figures: 3(a-e): ***Cratoneuroncommutatum,*** (3a) Morphology, (3b) Leaf mid portion, (3c) Leaf basal portion, (3d, 3e) Leaf cells.

Figures: 4(a-e): ***Cratoneuronfilicinum***(4a) Morphology, (4b) Leaf whole mount, (4c) Leaf tip cells, (4d) Leaf cells mid portion, (4e) Basal leaf cells.

Figures: 5(a-e): ***Drepanocladusexannulatus,*** (5a) Morphology, (5b) Leaf apex, (5c) Leaf marginal cells, (5d) Leaf cells basal portion, (5e) Basal leaf.

Figures: 6(a-e): ***Claopodiumassurgens,***(6a) Morphology, (6b) leaf whole mount, (6c) leaf apical cells, (6d) leaf marginal cells, (6e) leaf basal cells.

Figures: 7(a-e): ***Haplocladiummicrophyllum,*** (7a) Morphology, (7b) Leaf whole mount, (7c) Leaf apical cells, (7d) Leaf tip cells, (7e) Leaf basal cells.

Figures: 8(a-e): ***Lescuraeaincurvata,*** (8a) Morphology, (8b) Leaf whole mount, (8c) Leaf tip cells, (8d) Leaf apical cells, (8e) Leaf basal cells.

Figures: 9(a-e): ***Brachytheciumrivulare,*** (9a) Morphology, (9b) Leaf whole mount, (9c) Leaf apex, (9d) Leaf basal cells, (9e) Leaf cells.

Figures: 10(a-e): ***Osterwaldiellamonosticta,*** (10a) Morphology, (10b) Leaf whole mount, (10c) Apical leaf cells, (10d) Middle Leaf cells, (10e) Basal laminal cells.

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