Evaluation of Species Richness of Acrocarpous Mosses in Imphal District, Manipur, India

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ABSTRACT: Mosses are remarkably successful colonizer on the variety of habitats. They can survive in extreme environmental conditions where only a few other plants grow. The main attributes of mosses are compact growth form, ability to retain moisture, ectohydric nature, poikilohydry and low growing habit. The occurrence of a particular species may reflect the microclimate of the locality. The present study reveals 75 species of acrocarpous mosses belonging to 23 genera and nine families from Imphal district which is an urban site of tropical climate. The most frequently occurring family is observed to be Pottiaceae with 28 species and 11 genera. The genus *Bryum* with 13 species is found to have highest number of species followed by *Fissidens* and *Physcomitrium*. *Splachnobryum* sp. and *Bryum argenteum* are found to be distributed on the nitrophilous substrata. It seems that changing climatic conditions and pollution are restricting the sexual reproduction and subsequently the genetic variability and adaptability in the moss taxa.

KEY WORDS: Habitat specificity, Imphal, mosses, nitrophilous.

INTRODUCTION

Bryophytes are considered as first green plants that ventured on the barren land during the evolution of land flora and since then they have been following many morphological and physiological adaptations and various reproductive strategies to cope with the variable climatic and habitat conditions. Gametophyte phase of these plants is long-lived and independent and able to compete with higher plants which are sporophytic. Bryophytes constitute one of the species rich groups of land plants with about 18,000 species. Modern studies of cell ultrastructure and molecular biology established that they comprise of three distinct lineages, recognized as mosses (Bryophyta), represented by nearly 13,000 species and 700 genera, liverworts (Marchantiophyta) with 5,000 species and 390 genera and hornworts (Anthocerophyta) comprising nearly 150 species and 14 genera. Mosses comprise a noticeably more species rich group than the other two (Goffinet and Shaw, 2009; Goffinet et al., 2009).

Mosses are remarkably successful colonizers and can survive in extreme environmental conditions. The occurrence of a particular species may reflect the microclimate of the locality. Mosses are absent in the marine water, however a few are adapted to survive in salt marsh splash zone such as *Schistidium*, *Hyophila* etc. (Bates, 1975). Mosses and lichens and a few other plants have evolved a unique physiological adaptation which allows suspension of metabolism during periods of drought and its resumption when water is once available (poikilohydry) (Oliver, 2009). They tend to be highly specific with regard to particular micro-environmental factors such as temperature, light and water availability, substrate chemistry etc making them good ecological indicator species. They are ecologically significant in playing a key role in ecosystem dynamics (Vanderpoorten and Goffinet, 2009). Bryophytes are important stabilizers of substrate that later become suitable for colonization by other plants. Many small invertebrates are reported to be associated with mosses for shelter, food and oviposition (Gerson, 1982). Bryophytes play a significant role as indicators of environmental pollution and can be employed in developing an "Index of Atmospheric Purity" (IAP) (Bates, 2000). These plants have been successfully used to monitor metal and air borne pollution and indicators of climate change.

Mosses are low growing plants and their plant parts remain in contact with the substratum. The close position of individual shoots and branches make extensive capillary system, where water remains in the form of continuous stream. Water and nutrients are absorbed directly by thin leaves and stems. Mosses have undergone repeated morphological reduction and simplification often as a result of colonizing specialized and particularly xeric or ephemeral habitats (Vitt, 1981). The adaptation and structural modification caused regular speciation and resulted high species richness. Acrocarpous mosses have erect habit and intricate stems with limited growth as the apical cell is used in the formation of archegonia. The apex of stem

bears gametangia and subsequently the sporophyte. Acrocarpous mosses generally grow in the open areas, exposed and disturbed sites and are highly tolerant to harsh climatic conditions. They have shorter life span and high reproductive potential.

The knowledge of bryophytes in the extreme North-Eastern Himalayan regions has been somewhat hindered by in-adequate documentation. Imphal region of Manipur, the extreme North-eastern part of India was selected for the present study on the assessment of moss vegetation. Exploration is essential as there are chances for extinction of species before being acknowledged from these potential areas. The increasing activities of mankind may lead to the altering distribution patterns of bryophytes and subsequently may influence the functional and structural roles of species in the ecosystem. There is a need to document species ranges and make a comprehensive report on the bryophyte flora of this region to evaluate their role in ecosystem functioning and subsequently for the conservation of these species and their habitats. Present study deals with the distribution of acrocarpous mosses in the Imphal district of Manipur to have an insight on the species richness and their habitat preference.

STUDY AREA

Manipur state is located in the extreme northeastern border of India, between 23º51'N and 25º41'N latitude and 93º21'E and 94º47'E longitudes. The most striking topographic feature in this mountainous state is the central plain or Imphal plain known as Manipur basin which rests at an average altitude of 780 m. The area of the basin is 1,843 sq. km. which is only 8.25 percent of the total area of Manipur. Imphal district is taken as a study site which is located at 24°49'N, 93°57'E / 24.82°N, 93.95°E (Figs. 1A & B; Fig. 2). Imphal has a sub-tropical climate with cool, dry winters, a warm summer and a moderate monsoon season. July is the hottest month with temperatures averaging around 25°C, while January is the coldest with average temperature near 4°C. It gets about 1,320 mm of rainfall with June being the wettest month. The climatic conditions are suitable for a wide range of vegetation. The soils of Manipur are mostly clay, clay loam and sandy loam. The pH of soils ranges from 4.5 to 6.8 and their nitrogenous and phosphoric contents are moderate (Bhattacharya, 2006). The district has rich and varied vegetation consist of mostly mixed types, and the forest areas are mainly confined to hill areas (Figs. 3A & B). The important taxa include Bamboos *(Bambusa dendrocalmus)*, Teak *(Tectona grandis*), Pine *(Pinus insularis*) and Oak (*Quercus* sp).

Fig 1. Sampling site in this study. A: Manipur State in India. B: Map of Manipur showing Imphal (gray circle).

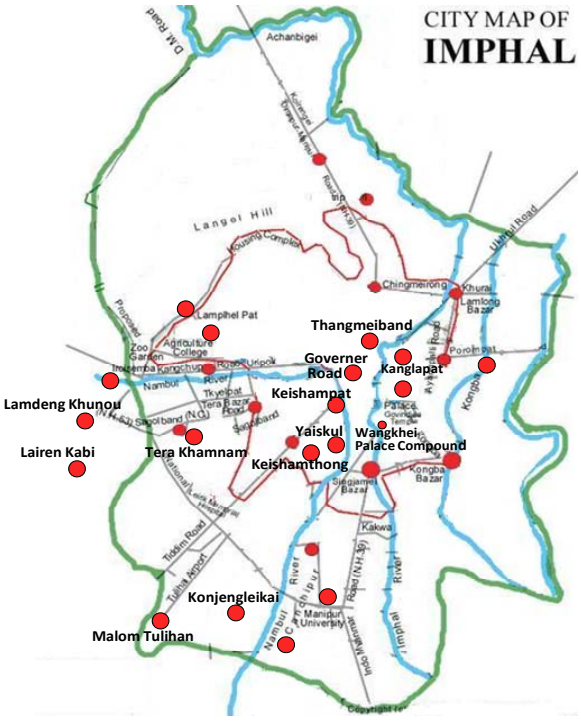

Fig. 2. Map of Imphal district showing study regions highlighted with gray circles.

MATERIAL AND METHODS

Collections of mosses were made from the different areas of Imphal district (Manipur), India (Figs. 2A & B) in the months of August – October**.** The patches of

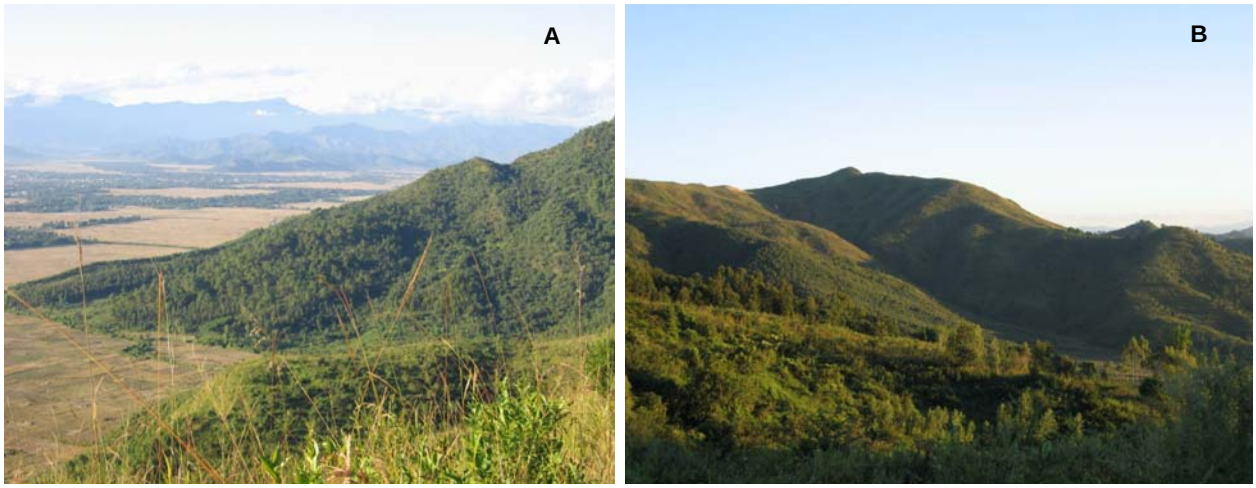

Fig. 3. A & B: A view of the plain and forest regions of the study area.

mosses were peeled off with a knife and collected in small polythene bags. Each population was kept separately and it is always emphasized to keep pure sample in one packet. The plant material was dried by spreading out on the blotting sheets for 3 – 4 days. Date of collection, locality and habitat along with the substratum type etc. were recorded in the field note-book and also on the packets containing the material. For the study the dried material is soaked in water for a few minutes in petridish. The different parts of the samples are taken out with the help of needles, brush and forceps and were carefully observed under the binocular microscope and compound microscope. In case of mixture of species in the sample which are closely intertwined, the entire mass is soaked in water and then separated into various species. Mosses were identified with the help of various Floras (Gangulee, 1969-1980; Chopra, 1975; Crum and Anderson, 1981; Watson, 1968). The list of acrocarpous taxa of mosses is given in Table.1. The taxa are arranged according to the classification of Goffinet et al. (2009). Voucher specimens are deposited in the Herbarium of the Department of Botany, University of Delhi, Delhi, India (DUH 13408-13484).

RESULTS AND DISCUSSION

The present study reveals 75 species of acrocarpous mosses belonging to 23 genera, nine families and seven orders (Table 1). The most frequently occurring family is found to be Pottiaceae with 28 species and 11 genera followed by Bryaceae with 22 species and five genera, Fissidentaceae with seven species of *Fissidens.* Funariaceae are found with seven species of two genera, Mniaceae with six species and two genera and Bartramiaceae with two species of *Philonotis.* Calymperaceae, Splachnaceae and Orthotrichaceae are found with one species and one genus each (Table 1 and Fig. 4). At the generic level, *Bryum* Hedw. with 13 species is found to have highest number of species. The genus *Fissidens* Hedw. is represented by seven species. *Brachymenium* Schwaegr., *Hyophila* Brid., *Physcomitrium* Brid., are represented by six species each. Other genera are represented by 1-2 species each in the study area. The species richness and abundance of taxa are categorized in the following manner:

Species of frequent occurrence

These species are recorded from more than five distant locations of the study area. *Barbula confertifolia* (Fig. 5S), *Bryum argenteum* var. *griffithii* (Fig. 7M), *Bryum argenteum* var. *lanatum* (Fig. 7N), *Bryum cellulare* (Fig. 7S), *Hyophila involuta* (Fig. 6M), *Mielichhoferia mielichhoferi* (Fig. 8H), *Physcomitrium eurystomum* (Fig. 5B) and *Semibarbula orientalis* (Fig. 6R) are of frequent occurrence. These species show high tolerance and adaptability and high regeneration potential and are able to grow in the variety of substrata.

Species with few populations

These species are found only in 2-3 locations of the study area. *Entosthodon wallichii, Physcomitrium repandum, Fissidens zollingeri, F. biformis, F. rigidiusculus, F. griffithii, F. virens, F. bilaspurense, F. ganguleei, Octoblepharum albidum, Anoectangium clarum, A. bicolor, Barbula tenuirostris, Bellibarbula kurziana, Bryoerythrophyllum recurvirostrum, Didymodon mittenii, Gymnostomiella vernicosa, Hyophila spathulata, H. kurziana, H. rosea, Hydrogonium amplexifolium, H. javanicum, H. arcuatum, H. pseudo-ehrenberghii, Semibarbula ranuii, Splachnobryum flaccidum, S. indicum, Tayloria*

Table 1. List of acrocarpous mosses recorded in Imphal district of Manipur, India.

SN	Name of the species and status	Growth form	Substratum	Distribution/Locality
ORDER- **FUNARIALES** Family- **Funariaceae**				
1	*Entosthodon wallichii* Mitt. (Fig. 5A)	Turf / Gregarious	Brick	Lamphelpat (**IW**)
2	*Physcomitrium eurystomum* Sendtn. (Fig. 5B)	Turf / Gregarious	Cement / Soil / Moist brick	Yaiskul hiruhanba (**IW**), Bamol leikai (**IW**), Keishamthong (**IW),** Khurukhul **(IW)**
3	*Physcomitrium indicum* (Dix.) Gangulee (Fig. 5C) , Endemic	Turf / Densely gregarious	Old dry wood	Tera khamnam (**IW**)
4	*Physcomitrium japonicum* (Hedw.) Mitt. (Fig. 5D)	Turf / Gregarious	Cement wall	Porompat (**IE),** Koirengei (**IW)**
5	*Physcomitrium pulchellum* (Griff.) Mitt. (Fig. 5E)	Turf / Caespitose	Disturbed soil	Yaiskul hiruhanba (**IW**),Postoffice (**IW**), Keishamthong (**IW**)
6	*Physcomitrium perflaccidum* Broth. ex. P.Vard. (Fig. 5F)	Turf	Soil	Chairenkhong khurai (**IE),** Tera khamnam (**IW)**
7	*Physcomitrium repandum* (Griff.) Mitt. (Fig. 5G)	Turf	Soil	Yaiskul hiruhanba **(IW)**
ORDER- **DICRANALES** Family- **Fissidentaceae**				
8	*Fissidens biformis* Mitt. (Fig. 5H)	Turf	Soil	Yaiskul hiruhanba (**IW**)
9	*Fissidens ganguleei* Norkett (Fig. 5I)	Turf	Soil	Tera (**IW**)
10	*Fissidens griffithii* Gangulee (Fig. 5J)	Turf	Soil	Tera (**IW)**
11	*Fissidens rigidiusculus* Broth. (Fig. 5K)	Turf	Sand	Yaiskul hiruhanba (**IW**)
12	*Fissidens splachnobryoides* Broth. (Fig. 5L)	Turf / Gregarious	Sandysoil / Lower trunk of *Mangifera indica*	Yaiskul Hiruhanba (**IW)**
13	*Fissidens virens* Thwait. & Mitt. (Fig. 5M)	Turf	Soil	Tera (**IW**)
14	*Fissidens zollingeri* Mont. (Fig. 5N)	Turf / Caespitose	Soil	Yaiskul hiruhanba (**IW**)
Family- **Calymperaceae**				
15	*Octoblepharum albidum* Hedw. (Fig. 5O)	Turf/ Compact	Bark of Date palm (*Phoenix dactylifera*)	Yaiskul hiruhanba (**IW**)
ORDER- **POTTIALES** Family- **Pottiaceae**				
16	*Anoectangium bicolor* Ren. & Card. (Fig. 5P)	Turf / Caespitose	Cement wall	Lamphelpat (**IW**)
17	*Anoectangium clarum* Mitt. (Fig. 5Q)	Turf / Caespitose	Cement / Brick wall	Yaiskul hiruhanba (**IW**)
18	*Barbula asperifolia* Mitt. (Fig. 5R)	Turf / Caespitose	Soil / Brick wall	Yaiskul Chingakham (**IW**), Koirengei **(IW)**
19	*Barbula confertifolia* Mitt. (Fig. 5S)	Turf / *Caespitose*	Clay soil / Cement wall / Soil / Open surface	Yaiskul hiruhanba (**IW**), Nongmaichingkhong (**IE**), Khurukhul **(IW)**, Lamphelpat **(IW)**.
20	*Barbula tenuirostris* Brid. (Fig. 5T)	Turf /Caespitose	Brick wall	Keishamthong (**IW).**
21	*Bellibarbula kurziana* Chen. (Fig. 6A)	Turf /Caespitose	Bark of *Ziziphus* sp.	Yaiskul hiruhanba (**IW**)
22	*Bellibarbula kurziana* var. *purpurescens* Gangulee. (Fig. 6B)	Turf / Caespitose	Brick wall	Keishamthong (**IW**)
23	*Bryoerythrophyllum ferrugineum* Gangulee. (Fig. 6C), Endemic	Turf / Caespitose	Brick wall	Chairenkhong khurai (**IE)**
24	*Bryoerythrophyllum recurvirostrum* (Hedw.) Chen. (Fig. 6D)	Turf / Caespitose	Brick wall	Yaiskul (**IW**)
25	*Didymodon mittenii* Gangulee. (Fig. 6E)	Turf / Caespitose	Soil	Yaiskul hiruhanba (**IW**)

Table 1. Continued.

SN	Name of the species and status	Growth form	Substratum	Distribution/Locality
	Family- **Pottiaceae**			
26	*Gymnostomiella vernicosa* (Hook.) Fleisch. (Fig. 6F)	Gregarious turf	Rock / Bark of *Azadirachta indica*, *Eucalyptus* spp.	Keishamthong (**IW**), Iroisemba **(IW)**, Lamphelpat **(IW)**
27	*Gymnostomum calcareum* Nees & Hornsch. (Fig. 6G)	Turf / Caespitose	Limestone rocks / Bark of *Ziziphus mauritiana*	Canchipur (**IW)**
28	*Hydrogonium amplexifolium* (Mitt.) Chen. (Fig. 6H)	Dense turf	Cement wall	Langol complex **(IW)**
29	*Hydrogonium arcuatum* (Griff.) Wijk & Marg. (Fig. 6I)	Turf	Soil stone	Kangla fort (**IW**)
30	*Hydrogonium javanicum* (Doz. & Molk.) Hilp. (Fig. 6J)	Dense turf	Soil / Brick	Langol complex (**IW**), Keishamthong (**IW)**
31	*Hydrogonium pseudo-ehrenbergii* (Fleisch.) Chen. (Fig. 6K)	Thick turf	Soil stone / Cement wall	Sanjenthong (**IE**)
32	*Hyophila comosa* Dix. *et* Varde. (Fig. 6L)	Turf / Interrupted rosettes	Brick wall or cement wall.	Yaiskul (**IW**),Sanjenthong (**IE**), Chingmeirong (**IE**), Canchipur **(IW)**.
33	*Hyophila involuta* (Hook.) Jaeg. (Fig. 6M).	Dense turf	Cement floor / Bricks / Mortar / Small rocks	Yaiskul (**IW**), Indira park (**IW**), Keishamthong (**IW**) Keishampat (**IW**), Khurai (**IW**), Lamphelpat (**IW**) Lamdengkhunou (**IE**) Malom (**IW**), Porompat (**IE**), Khurukhul **(IW)** Chingmeirong (**IE**)
34	*Hyophila kurziana* Gangulee (Fig. 6N)	Turf	Brick wall	Wahengleikai (**IW),** Khurai (**IE**)
35	*Hyophila perannulata* Ren. *et* Card. (Fig. 6O), Endemic	Turf /Caespitose	Brick wall	Keishamthong **(IW)**
36	*Hyophila rosea* Williams. (Fig. 6P)	Turf /Laxly caespitose	Cement wall / Brick wall	Yaiskul (**IW**),Tera (**IW**), Wahengleikai (**IW**),
37	*Hyophila spathulata* (Harv.) Jaeg. (Fig. 6Q)	Turf	Moist Brick wall / Cement wall.	Sanjenthong (**IE**), Yaiskul (**IW**).
38	*Semibarbula orientalis* (Web.) Wijk. & Marg. (Fig. 6R)	Dense turf	Calcicole rock / Soil / Cement convert / Bark of dry wood	Keishamthong **(IW),** Tera Sangolband (**IW**), Yaiskul Chingakham (**IW**), Yaiskul hiruhanba (**IW**), Langol complex (**IW**), Chingmeirong (**IE**), Keishampat (**IW**), Indira park (**IW**), Chairenkhong khurai (**IE**), Lamphelpat (**IW**), Kanglapat (**IW**), Malom (**IW**)
39	*Semibarbula ranuii* Gangulee. (Fig. 6S)	Loose turf	Cement wall / Soil / Rock surfaces / Shady area	Wangkhei (**IE**), Yaiskul hiruhanba (**IW**)
40	*Splachnobryum bengalense* Gangulee. (Fig. 6T), Endemic	Dense turf	Cement wall / Brick / Clay soil / Moist soil	Yaiskul Chingnakham (**IW**), Tera khamnam Leirak (**IW)**
41	*Splachnobryum flaccidum* (Harv.) Braithw. (Fig. 7A)	Turf	Soil	Chingmeirong (**IE**),
42	*Splachnobryum indicum* Hamp. & C.Muell. (Fig. 7B)	Dense turf	Cement wall / Floor	Tera Sangolband (**IW**)
43	*Splachnobryum synoicum* Robinson. (Fig. 7C), Endemic	Turf / Laxly caespitose	Brick floor	D.M. College of Science Campus, Thangmeiband (**IW)**
ORDER- **SPLACHNALES** FAMILY-**Splachnaceae**				
44	*Tayloria hornschuchii* (Grev. & Arnott) Broth. (Fig. 7D)	Dense turf	Soil	Keishamthong kabhui khun (**IW)**
ORDER- **BRYALES** Family- **Bryaceae**				
45	*Anomobryum auratum* (Mitt.) Jaeg. (Fig. 7E)	Dense turf / julaceous	Soil on small stone	Yaiskul police lane (**IW)**
46	*Brachymenium acuminatum* Harv. (Fig. 7F)	Dense mats	Brick wall	Chairenkhong khurai (**IE)**
47	*Brachymenium bryoides* Hook. *ex* Schwaegr. (Fig. 7G)	Turf /Gregarious	Dry wood / Soil	Yaiskul police lane (**IW),** Khurukhul **(IW)**
48	*Brachymenium indicum* (Doz. & Molk.) Bosch & Lac. (Fig. 7H)	Dense turf	Soil / Cement wall	Kanglatombi (**IE),** Canchipur **(IW)**

Table 1. Continued.

SN	Name of the species and status	Growth form	Substratum	Distribution/Locality
	Family- **Bryaceae**			
49	*Brachymenium longicolle* Ther. (Fig. 7I)	Turf	Cement roof	Khongman **(IE)**
50	*Brachymenium ochianum* Gangulee. (Fig. 7J)	Dense turf	Cement wall	Yaiskul Chingnakham **(IW)**
51	*Brachymenium sikkimense* Ren. & Card. (Fig. 7K), Endemic	Gregarious / Dense	Cement wall	Keishamthong (**IW**), Langthaban **(IE)**
52	*Bryum alpinum* Huds. *ex* With. (Fig. 7L)	Turf rigid	Brick wall	Lamphelpat **(IW)**
53	*Bryum argenteum* var. *griffithii* (C.Muell.) Gangulee. (Fig. 7M)	Turf	Cement wall / Rocks	Khongman **(IE),**Bamon Leikai **(IE),** Langthaban**(IW),**Yaiskul Police Lane **(IW)**, Yaiskul Chingakham **(IW)**
54	*Bryum argenteum* var. *lanatum* (P.Beauv.) Hamp. (Fig. 7N)	Dense turf	Cement / Soil / Brick wall	Keishamthong **(IW)**
55	*Bryum atrovirens* Brid. (Fig. 7O)	Turf	Sandy soil	Tera khamnam leirak **(IW)**
56	*Bryum badhwari* Ochi. (Fig. 7P)	Dense caespitose	Soil	Khurukhul **(IW)**
57	*Bryum caespiticium* Hedw. (Fig. 7Q)	Dense caespitose	Brick wall	Chairenkhong khurai **(IE)**
58	*Bryum capillare* var. *spininervium* Dix. (Fig. 7R)	Turf	Cement / Soil / Brick wall	Keishamthong **(IW)**
59	*Bryum cellulare* (Hook.) Schwaegr. (Fig. 7S)	Dense turf	Cement wall / Soil / Brick wall / Cement floor	Keishamthong **(IW),** Yaiskul Chingnakham **(IW),** Palace compound **(IE),** Chingmeirong **(IE),** Chairenkhong khurai **(IE)**
60	*Bryum intermedium* (Brid.) Bland. (Fig. 7T).	Turf	Cement wall	Keishampat (**IW)**
61	*Bryum plumosum* (Dox. & Molk.) (Fig. 8A)	Turf	Brick / Cement floor / Flower pot	Wangkhei (**IE**), Keishamthong **(IW)**
62	*Bryum porphyroneuron* var.*erythrinum* (Mitt.) Fleisch. (Fig. 8B)	Loose turf	Brick	Lamphelpat **(IW)**
63	*Bryum pseudotriquetrum* C. Muell. (Fig. 8C)	Robust turf	Brick	Lamphelpat **(IW)**
64	*Bryum pseudotriquetrum* var. *rotundum* (Hedw.) Schwaegr. (Fig. 8D)	Turf robust	Wet Soil	Yaiskul police lane **(IW)**
65	*Mniobryum wahlenbergii* (Web.et Mohr.) Jenn. (Fig. 8E)	Lax turf	Cement roof	Khurukhul (**IW)**
66	*Plagiobryum zierii* (Hedw.) Lindb. (Fig. 8F)	Close turf	Cement wall	Keishamthong **(IW)**
	Family- **Mniaceae**			
67	*Mielichhoferia badhwarii* Dix. (Fig. 8G)	Turf	Soil	Yaiskul police lane (**IW)**
68	*Mielichhoferia mielichhoferi* (Hook.) Wijk & Marg. (Fig. 8H)	Dense turf	Soil / Cement wall	Bamon leikai (**IE**), Wangkhei (**IE),** Keishampat (**IW**), Kanglapat post Office **(IW**) Chairenkhong khurai (**IE)**
69	*Pohlia minor* var. *acuminata* (Hopp. & Hornsch.) Wijk & Marg. (Fig. 8I)	Loose turf	Soil	Chairenkhong khurai (**IE)**
70	*Pohlia flexuosa* Hook. (Fig. 8J)	Lax turf / Gregarious	Cement wall / Soil	Keishamthong (**IW)**
71	*Pohlia gedeana* (Bosch & Lac.) Gangulee. (Fig. 8K)	Dense turf / Loose	Brick wall / Soil	D.M.College of Science, Thangmeiband (**IW),** Khurukhul **(IW)**
72	*Pohlia rigescens* (Mitt.) Broth. (Fig. 8L)	Dense turf / Loose	Soil	Tera khamnam Leirak (**IW)**
ORDER- **BARTRAMIALES** Family- **Bartramiaceae**				
73	*Philonotis hastata* (Dub.) Wijk & Marg. (Fig. 8M)	Turf	Soil	Yaiskul hiruhanba **(IW)**
74	*Philonotis leptocarpa* Mitt. (Fig. 8N)	Caespitose	Black soil / Brick stair case	Lairen phabi **(IW)**
ORDER- **ORTHOTRICHALES** Family- **Orthotrichaceae**				
75	*Hypnodon* sp. (Fig. 8O)	Turf	Bark of *Azadirachta indica*, *Parkia* spp., *Salix tetrasperma*	Malom **(IW)**

***IW** = West Imphal; **IE** = East Imphal.

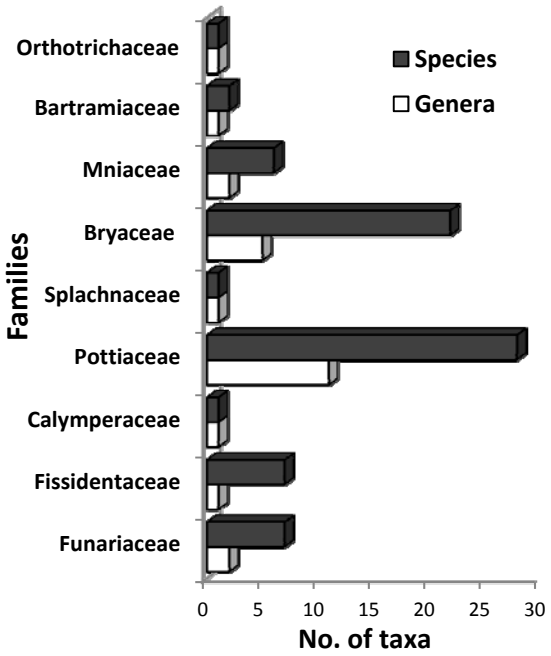

Fig. 4. Number of taxa recorded in the families.

hornschuchii, Anomobryum auratum, Brachymenium bryoides, B. ochianum, B. longicolle, B. indicum, Brachymenium acuminatum, Bryum capillare, B. pseudotriquetrum, B. caespiticium, B. badhwari, B. atrovirens, B. alpinum, B. porphyroneuron, B. plumosum, Mniobryum wahlenbergii, Plagiobryum zierii, Mielichhoferia badhwarii, Pohlia flexuosa, P. minor, P. gedeana, P. rigescens, Philonotis hastata, P. fontana and *Hypnodon* sp.

Species endemic to India

Species such as *Brachymenium bryoides* (Western Himalaya, South India), *Brachymenium sikkimense* (Darjeeling, Northeast (NE) Himalaya) (Fig. 7 K), *Bryoerythrophyllum ferrugineum* (Darjeeling, NE Himalaya) (Fig. 6C), *Hyophila comosa* (South India) (Fig. 6L), *Hyophila kurziana* (Darjeeling, NE Himalaya) (Fig. 6 N), *Hyophila perannulata* (NE Himalaya) (Fig. 6O), *Physcomitrium indicum* (West Bengal, Northern region of India) (Fig. 5C), *Semibarbula ranuii* (Bihar) (Fig. 6S), *Splachnobryum bengalense* (West Bengal) (Fig. 6T) and *Splachnobryum synoicum* (Upper Assam) (Fig. 7C) are the endemic acrocarpous species (Gangulee, 1969-80) recorded from the presently studied region.

Acrocarpous mosses are considered more drought tolerant than pleurocarpous taxa. Most of the taxa are found growing on hard substrata like cement wall/bricks wall and soil. *Hyophila involuta* (Fig. 6M), *Semibarbula orientalis* (Fig. 6R) and *Bryum argenteum* are found to show wide distribution. This may be because of the precise micro-environmental conditions that are repeated in different habitats. *Hyophila involuta* is observed to be a common invader of every type of substrate such as rocks, cement floor, bricks, mortar, small rocks and boulders. *Hyophila*, *Semibarbula* and *Bryum* sp. are presumed to be highly tolerant to drought, disturbance, pollution etc. They have a high reproductive potential and found with capsules as well as gemmae. However, many of the taxa are found in sterile conditions in the study site which indicate their reproduction by vegetative means only.

Bryum argenteum (Figs. 7M & N) constitutes an important part of the colonization on nitrogenous substrates. Its repeated occurrence and abundance spread over nitrogenous substrate indicate its nitrophilous nature (Richards, 1932; Bodenberg, 1954; Watson, 1968). It invades the scattered bricks, pavements, cement walls, gravel, foot-paths immediately after a shower and spread abundantly over such regularly trampled sites in the form of green-line. *Bryum capillare* (Fig. 7R) interspersed with *Bryum argenteum* act as efficient "traps" and accumulate large quantities of soil or humus. *Bryum argenteum* and *Hyophila involuta* (Fig. 6M) occurs in a wide range of habitats which indicate that these plants have broad ecological amplitudes. *Hyophila involuta* is found growing on calcium and magnesium rich substrata and also found to occupy exposed surfaces of rocks and boulders having no trace of vegetation. It is found mixed with colonies of *Bryum cellulare* (Fig. 7S), *Semibarbula orientalis* (Fig. 6R), *Bryum argenteum* (Fig. 7M), *Gymnostomum calcareum* (Fig. 6G), *Brachymenium acuminatum* (Fig. 7F) and *Bryum capillare*. *Mielichhoferia* (Fig. 8H) is found to occur on sites of ore deposits or other metallic concentrations of copper, iron, lead and zinc as also reported by Shacklette (1967).

Hydrogonium javanicum (Fig. 6J) is mostly collected from the tufaceous deposits. The weathered, moist, soil-covered soapstone boulders constantly bathed with water supports a lush green mossy covering of *Anoectangium* (Figs. 5P & Q), *Pohlia* (Fig. 8I) and *Splachnobryum* sp. (Fig. 6T). *Anoectangium*, *Gymnostomum* (Fig. 6G) and *Philonotis* (Figs. 8M & N) are observed to be calcicole. *Bryum pseudotriquetrum* (Fig. 8C) prefers limonitic, strongly acidic substrates. Turf growth form is found to be dominant in the study area and their distribution can be correlated with the local climate. Some green algae are also found to be associated with moss colonies of the collected taxa.

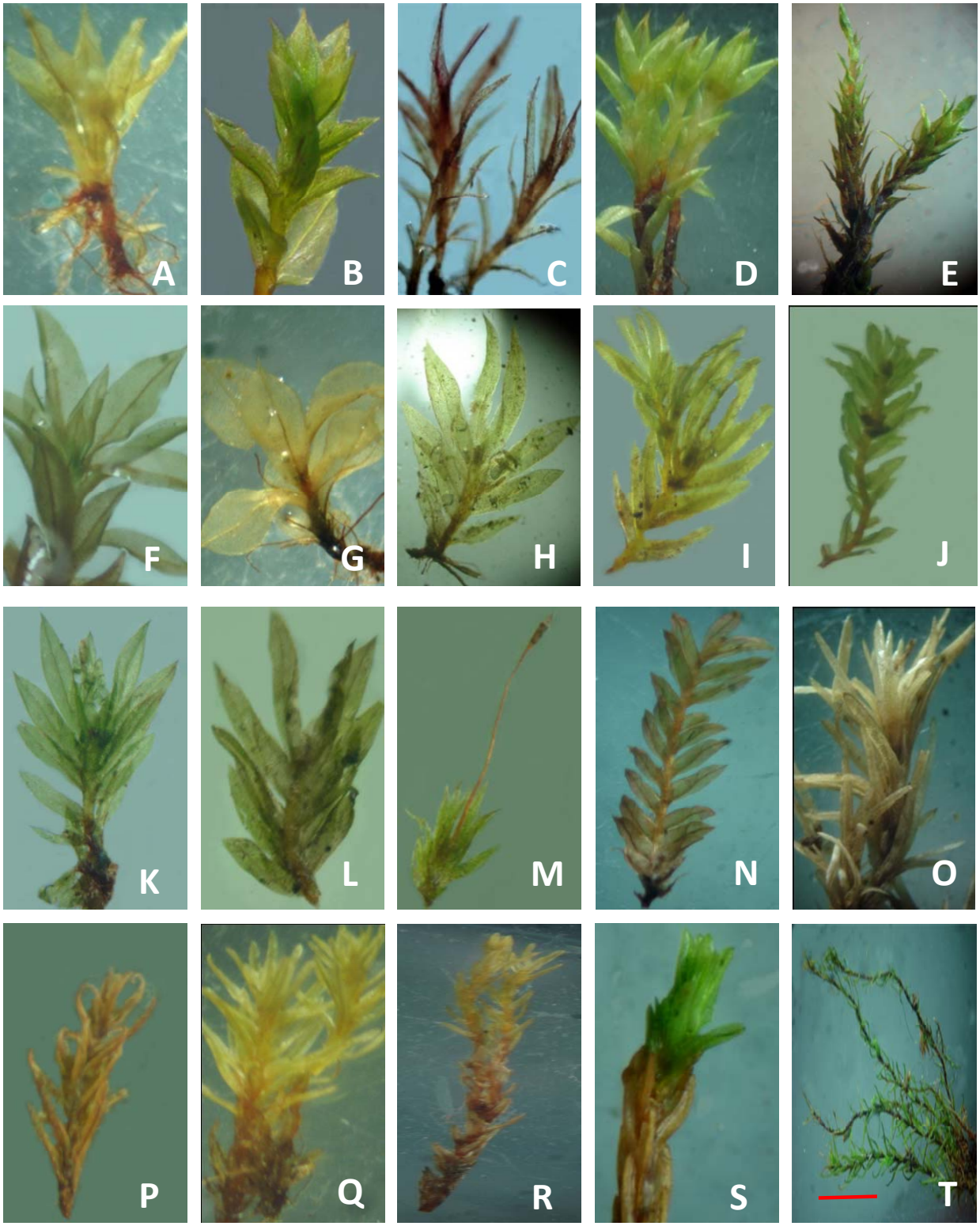

Fig. 5. Acrocarpous mosses in Imphal District, Manipur, India. A: *Entosthodon wallichii.* B: *Physcomitrium eurystomum.* C: *P. indicum.* D: *P. japonicum.* E: *P. pulchellum.* F: *P. perflaccidum.* G: *P. repandum.* H: *Fissidens biformis.* I: *F. ganguleei.* J: *F. griffithii.* K: *F. rigidiusculus.* L: *F. splachnobryoides.* M: *F. virens.* N: *F. zollengeri.* O: *Octoblepharum albidum.* P: *Anoectangium bicolor.* Q: *A. clarum.* R: *Barbula asperifolia.* S: *B. confertifolia.* T: *B. tenuirostris.* Scale bar = 1 cm.

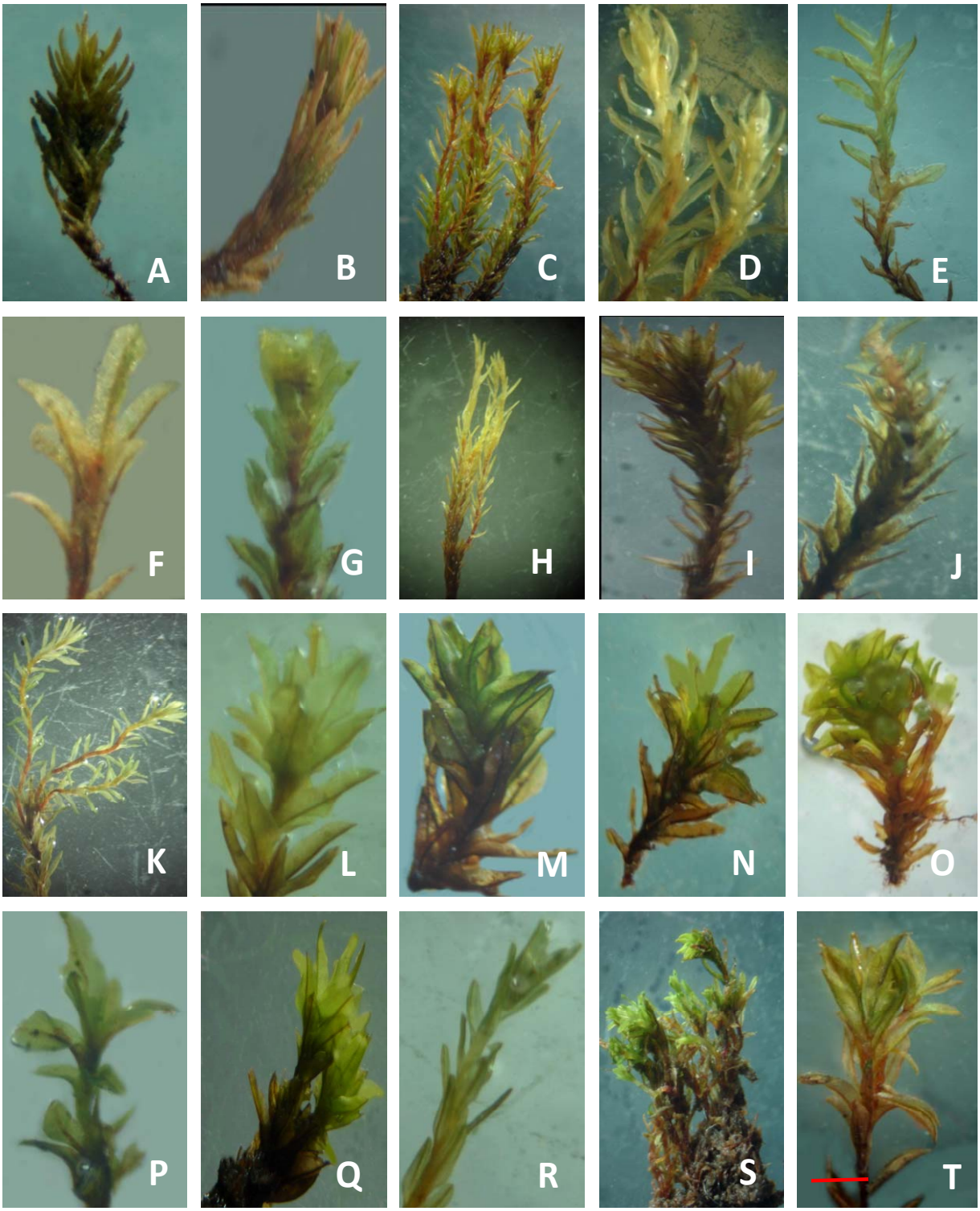

Fig 6. Acrocarpous mosses in Imphal District, Manipur, India. A: *Bellibarbula kurziana.* B: *B. kurziana* var. *purpureus.* C: *Bryoerythrophyllum ferrugineum.* D: *B. recurvirostrum.* E: *Didymodon mittenii.* F: *Gymnostomiella vernicosa.* G: *Gymnostomum calcareum.* H: *Hydrogonium amplexifolium.* I: *H. arcuatum.* J: *H. javanicum.* K: *H. pseudo-ehrenberghii.* L: *Hyophila comosa.* M: *H. involuta.* N: *H. kurziana.* O: *H. perannulata.* P: *H. rosea.* Q: *H. spathulata.* R: *Semibarbula orientalis.* S: *S. ranuii.* T: *Splachnobryum bengalense.* Scale Bar = 1 cm.

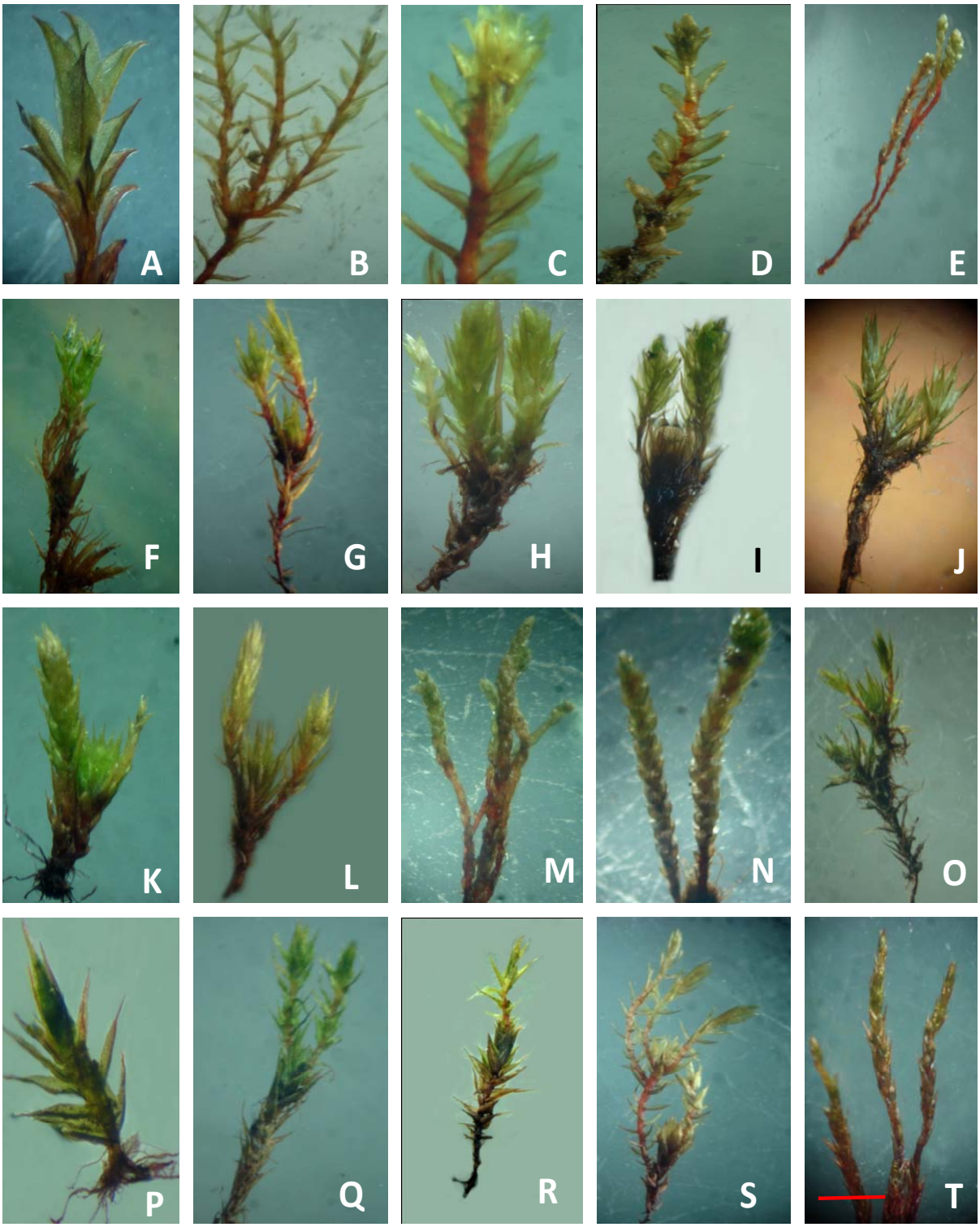

Fig. 7. Acrocarpous mosses in Imphal District, Manipur, India. A: *Splachnobryum flaccidum.* B: *S. indicum.* C: *S. synoicum.* D: *Tayloria hornschuchii.* E: *Anomobryum auratum.* F: *Brachymenium acuminatum.* G: *B. bryoides.* H: *B. indicum.* I: *B. longicolle.* J: *B. ochianum.* K: *B. sikkimense.* L: *Bryum alpinum.* M: *B.argenteum* var. *griffithii.* N: *B. argenteum* var. *lanatum.* O: *B. atrovirens.* P: *B. badhwari.* Q: *B. caespiticium* R: *B. capillare.* S: *B. cellulare.* T: *B. intermedium.* Sacle bar = 1 cm.

Fig. 8. Acrocarpous mosses in Imphal District, Manipur, India. A: *Bryum plumosum*. B: *B. porphyroneuron* var. *erythrinum*. C: *B. pseudotriquetrum*. D: *B. pseudotriquetrum* var. *rotundum*. E: *Mniobryum wahlenberghii*. F: *Plagiobryum zierii*. G: *Mielichhoferia badhwarii*. H: *M. mielichhoferi*. I: *Pohlia minor* var. *acuminate*. J: *P. flexuosa*. K: *Pohlia gedeana*. L: *Pohlia rigescens*. M: *Philonotis hastata*. N: *Philonotis leptocarpa*. O: *Hypnodon* sp. Scale bar = 1 cm.

CONCLUSIONS

In the light of immense ecological role and maintenance of micro-ecosystem by mosses there is a pressing need for population level studies with respect to ecological diversity, reproductive strategy and habitat requirement. Many taxa are observed only in sterile conditions, probable the changing climate and pollution are preventing the gametangial formation and fertilization. Such situation leads to the less genetic variability and subsequently decreases the ability of adaptation. Specific habitats preference restricts the distribution of some species and may be responsible in part for their rare or endangered status. The ability of accumulation of pollutants may be an important aspect of application of these species in the bioindicators and phytoremediation programmes. Broad scale studies within a wide range of species at different altitude and habitats are urgently needed. Multidisciplinary approaches of ecology and floristics will allow us to

understand how reproductive strategies changes within and among species at different habitats conditions, which will address the possible consequences of global warming.

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印度曼尼普爾邦因帕爾地區頂生蒴苔類植物物種豐富度之評估

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摘要：苔類植物是一群可以成功建立於各種生境的拓殖者。他們能生活於僅少數植物能生長的極端環境條件之中。苔類植物主要的特徵有：袖珍而完整的生長方式、維持潮濕的能力、外導水的（ectohydric）特性、缺乏抗乾燥機制的變水性質（poikilohydry），及低小的生活型體。苔類物種也具有指標性，某一特定物種的出現可能反映該地區的微氣候環境。本研究報導於一個地處熱帶氣候的都市 – 因帕爾地區，當地的苔類植物相；研究中共調查到 9 科，23 屬，75 種頂生蒴的苔類植物。其中所觀察到的科頻率最高為 Pottiaceae 具有 11 屬，28 種。*Bryum* 包含有 13 個物種為最多物種的屬，其次為 *Fissidens* 和 *Physcomitrium* 二屬。*Splachnobryum* sp. 及 *Bryum argenteum* 被發現分布於高含氮的基質。本文顯示氣候條件的改變及環境的污染正約制著苔類植物的有性繁殖，隨後可能減低苔類植物的遺傳變異以及其適應性。

關鍵詞：生境的特殊性、因帕爾地區、苔類植物、嗜氮性（Nitrophilous）。