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CHAPTER

Bryofloral Diversity: Distribution and Conservation of Amphibian Members of Plant Kingdom in India

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ABSTRACT

Bryophytes are group of non-vascular, amphibian members of plant kingdom having huge diversity in India with about 2489 taxa comprising of 1786 species. This plant group is subdivided into three phylogenetic lineages namely Hepaticopsida, Anthocerotopsida and Bryopsida that are distributed throughout India mostly in moist, highly elevated pollution free areas. Synecological studies with bryophytes involve different bryofloral communities and societies in relation to the ecological conditions such as water, temperature, light and edaphic factors. Bryophytes cross talks with insects, microarthropods, springtails, birds and play an important role in maintaining stability of ecological dynamics. Due to constant human interference, conservation strategies are required to protect sufficient large natural asset that are facing tremendous threat. Bioprospecting of bryophytes is done for the production of bioactive phytochemicals that have potential pharmaceutical and pharmacological uses but still a larger fraction of bryofloral wealth is hidden and unexplored.

Keywords: Bryophytes, bioprospecting, conservation, distribution, diversity, ecology.

INTRODUCTION

Bryophytes are highly specialized, non-vascular, oldest group of living land plants, considered to be the amphibians of plant kingdom for its dependence on water for the completion of life cycle. This amphibious situation in bryophytes can be hypo-

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thetically correlated with human lives which when present as developing human embryo in the mother's womb swims in water and just after birth finds itself on land. Robert Brown first coined the term 'Bryophyta' in 1864 that included the algae, fungi, lichens and mosses but in recent years this term is used to represent only the members of non-vascular cryptogams with about 25,000 species worldwide (Buck and Goffinet, 2000). The characteristic features of bryophytes show resemblances with green algae possessing a common ancestor. These amphibians have been originated around Devonian period and form a basal phylogenetic position among extant land plants. However, recent phylogenetic reconstruction suggest that hornworts form the basal group to higher land plants; mosses, and liverworts forms a monophyletic sister clade.

Bryophytes have the property of enduring and surviving under stressful conditions such as drought, cold, shades and nutrient deficient conditions which provoked these plants to develop alternative strategy of evolving stress tolerance. They are capable of growing at moist conditions, photosynthesizing and suspending metabolism during desiccation stress thereby playing an important role in ecosystem by influencing factors such as soil temperature, nutrient input, carbon sequestration and many other factors. Due to their netted and webbed protonemata and gametophores, bryophytes protect the soil against erosion and thereby help to increase the water-holding capacity of the soil. Due to their trample-resistant structure and their regenerative capacity, mosses like *Pogonatum, Pohlia, Atrichum, Nardia,* and *Trematodon* act as bodyguard of soil against erosion. Besides these bryophytes play an important role in nutrient cycling (Coxson, 1991) as well as in provides an ambient microhabitat for other plants.

2. Bryofloral Diversity Spectrum

India is among one of those candidates in the world known to possess a mega-biodiversity with an immense variety of phyto-seasonal and altitudinal variations within her biogeographical zones. This feature contributes to the rich vegetational wealth which makes the Indian floral diversity a unique one The east and west coast of peninsular India i.e., Eastern and Western Ghats and lofty mountains of the Himalayas in the North-east and North-west together with Central India provides home to huge spectra of bryofloral diversity. Singh and Sinha (1997) broadly classified Indian sub-continent into eight biogeographical regions that included the Eastern and Western Himalayas, the Gangetic plains, the Punjab and West Rajasthan plains, Cental India, the Eastern Ghats and Deccan Plateau, the Western Ghats and lastly the Andaman and Nicobar islands.

The Bryophyte is such a distinctive and diversified group of plants that it may be easily considered as a distinct Division in plant kingdom. Rothmaler (1951) divided the Division Bryophyta into three classes namely Hepaticopsida (Liverworts), Anthocerotopsida (Hornworts) and Bryopsida (Mosses). According to the last available checklist of bryophytes in India provided by Dandotiya *et al.*, (2011) reported about 2489 taxa consisting of 1786 species that included 355 genera of mosses, 25 species in 6 genera of hornworts and 675 species in 121 genera of liverworts (Fig. 1) from India. Other researchers also reported a few genera in these three groups that are found to have large number of species diversity namely in liverworts like *Riccia, Porella, Jungermannia, Frullania, Lejeunea* and *Plagiochila*; in hornworts like *Anthoceros*; and in mosses like *Bryum, Barbula, Campylopus and Fissidens*. The families like Notothyladaceae, Pottiaceae and Lejeuniaceae are found to be highly represented in India. Besides these, around 340 species have been reported as endemic of which ca. 67 species are liverworts, 4 species are of hornworts and 269 species are of mosses and considering the status of Threatened categories as per recent IUCN Red List of Threatened Species which included nearly 14 species as endangered species and 133 species as rare species of which 53 are liverworts and 78 are mosses (Figure 1). Rawat *et al.*, (2016) has provided an updated account on mosses thriving in and around Gangetic plains that included 79 taxa of mosses with 19 families and 40 genera. The genus *Fissidens* with 19 species showed maximum diversity followed by *Physcomitrium* and *Hyophila* with 5 species each at generic level and at family level. Pottiaceae appeared

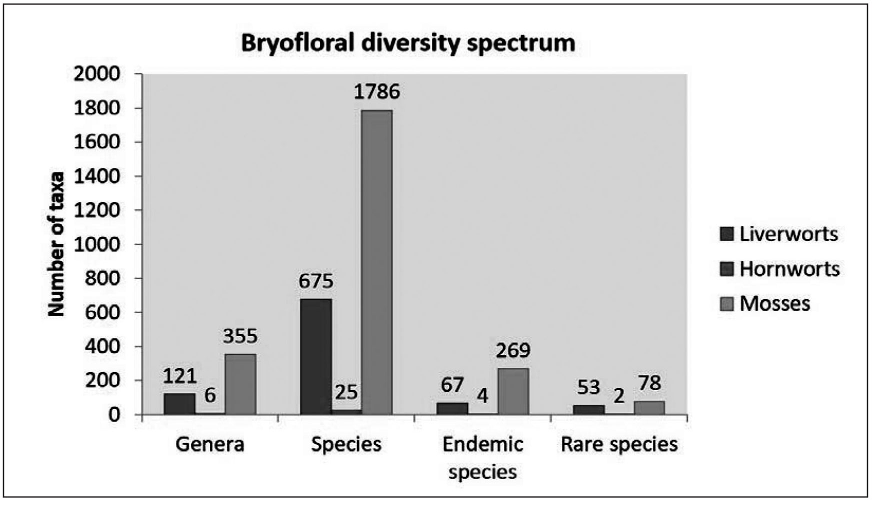

Fig. 1. Shows bryofloral diversity spectrum in India depicting number of genera, species, endemic species and rare species present in each of these three phylogenetic groups-Liverworts, Hornworts and Mosses.

to be most dominant and diversified family with 17 taxa belonging to 9 genera in and around the plains.

In this chapter, Bryophytes have been considered as Division and divided into three classes in accordance with the classification as provided by Rothmaler (1951). With the introduction of molecular biology techniques and the ultrastructure of the cell confirmed that bryophytes have three separate evolutionary lineages namely

Liverworts (Hepaticopsida), Hornworts (Anthocerotopsida) and Mosses (Bryopsida) (Shaw and Goffinet 2000). These three phylogenetic lineages are discussed very briefly to highlight the uniqueness of bryofloral diversity followed by discussion on habitats that deserve greater attention in near future with a view of conserving this rich Indian resource.

2.1. Hepaticopsida (Liverworts)

General features- Hepaticopsids are recognized by their dorsiventral differentiated gametophytes sometimes with erect and radial system possessing a thalloid or foliose arrangement without nerves. Singh (2001) reported around 850 species of liverworts belonging to 52 families and 141 genera. Dandotiya *et al.*, (2011) reported 675 species of liverworts belonging 121 genera. Leafy liverworts i.e., the members of Order Jungermanniales constitute around 85 percent of total liverwort species and the gametophytes of a majority are foliose in nature. The identification of some species of mosses and leafy liverworts can be confirmed with aid of microscopy and experienced bryologists due to their similar physical resemblance.

Common species: Some common species of leafy liverworts are *Pellia, Porella, Frullania, Cololejeunea, Asterella, Radula*.

Habit and habitat: Liverworts are usually small in size around 2-25 mm with an individual plant less than 10 cm covering large patches of ground, trees, rocks or any other firm substratum. They are mostly distributes in moist, shady, semi-aquatic, terrestrial, humid locations especially in high altitudes.

Gametophyte: Liverworts have a gametophyte dominant life cycle with fully dependent sporophyte on the gametophyte. Sex organs are borne terminally or from superficial dorsal cells with sex organs of some species are borne on special branches called antheridiophore (Fig. 2B) and archegoniophore (Fig. 2C) as found in *Marchantia* spp.

Sporophyte: The sporophyte is simple having only spore-case as in *Riccia sp.* (Fig. 2A) or differentiated into foot, seta and capsule which are always limited in their growth. The spores are liberated either by complete decay of venter wall as in *Riccia* spp. (Fig. 2A) or by the movement of spindle-shaped hygroscopic elaters in the air by splitting of sporophyte into four segments.

2.2. Anthocerotopsida (Hornworts)

General features- Anthocerotopsids are recognized by their dorsiventrally differentiated gametophytic simple thalloid structures and are not foliose.

The name Hornworts refer to the elongated horn like structure of the sporophyte. Renzaglia and Vaughn (2000) reported around 100-150 species of hornworts in the world of which 25 species belongs to 6 genera.

Common species: Some common hornworts found in India are *Anthoceros, Notothylas, Folioceros, Phaeoceros, Megaceros* and *Hattoriceros*.

Habit and habitat: As compared to liverworts, hornworts are larger in size and most interestingly the spores of hornworts are relatively large for bryophytes measuring around 25-70 µm in diameter or more. These tend to grow in damp and humid places whereas some species are also found to grow in cultivated lands as well as in soil as growing weeds. Large tropical species of *Dendroceros* are also found to grow on bark of trees.

Gametophyte: The thallus of most hornworts consists of one chloroplast which in most species fuses with several organelles to form large central pyrenoid resembling green alga *Coleochaete* and function in production and storage of food. Their internal structure shows mucilage filled cavities which are invaded by photosynthetic cyanobacteria mostly of *Nostoc* species that develop symbiotic association with the hornworts providing organic nitrogen for metabolism of the host and receiving food and shelter from the host in return. Sex organs are embedded in the gametophyte.

Sporophyte: The sporophyte is differentiated into foot, the lowermost cells of which are haustorial and erect, cylindrical, horn-like capsule,The lower part of the capsule shows unlimited growth because of characteristic intercalary meristem. The presence of stomata on the epidermal tissue and central sterile columella also indicates the advance features of the sporophyte. The spores are liberated when the capsule becomes matured and the hygroscopic movement of the pseudoelaters releases these mature spores from the top of the capsule as seen in case of *Anthoceros* spp.

2.3. Bryopsida (Mosses)

General features- The characterization of bryopsids initially begins with a short protonemal phase which further develop erect shoots that are usually radially symmetrical with stem like caulids and leafy appandages like phyllids. The general structure of a moss is shown in Figure E. Bahuguna *et al.*, (2013) reported around 2300 species belonging to 330 genera. Dandotiya *et al.*, (2011) reported around 355 genera of mosses in India.

Common species: There are many common mosses but to name a few are *Sphagnum, Andreaea, Funaria, Pogonatum, Polytrichum, Mnium, Semibarbula, Bryum* etc.

Habit and habitat: Mosses usually range from 0.2-10 cm in height though some species are much larger like the tallest moss in the world, *Dawsonia* which is around 50 cm tall. Mosses usually grow as dense green mats or as clumps often in damp, moist and shady places and sometime contributes more than 50 percent of active biomass (Groombridge, 1992).

Gametophyte: The gametophyte of mosses are characterized by prostrate, branched, filamentous, thalloid protonema that later develops into leafy gametophytes. The rhizoids are multicellular with cross walls. The leaves are spirally arranged and the sectional view of the leaves of *Sphagnum* sp. (Fig. 2D) shows a regular reticulate pattern of hyaline and chlorophyllose cells and these hyaline cells play an important role in water absorption and retention. Sexual organs develop from superficial cells at the top of axillary and apical mersitems of gametophytes.

Sporophyte: The sporophyte is differentiated into foot, seta and capsule as clearly shown in Fig. 2E. The tip of the capsule as found in *Funaria* sp. possess teeth like structures known as peristome teeth (Fig. 2F)) that are of two sets- outer peristome with transverse bars and

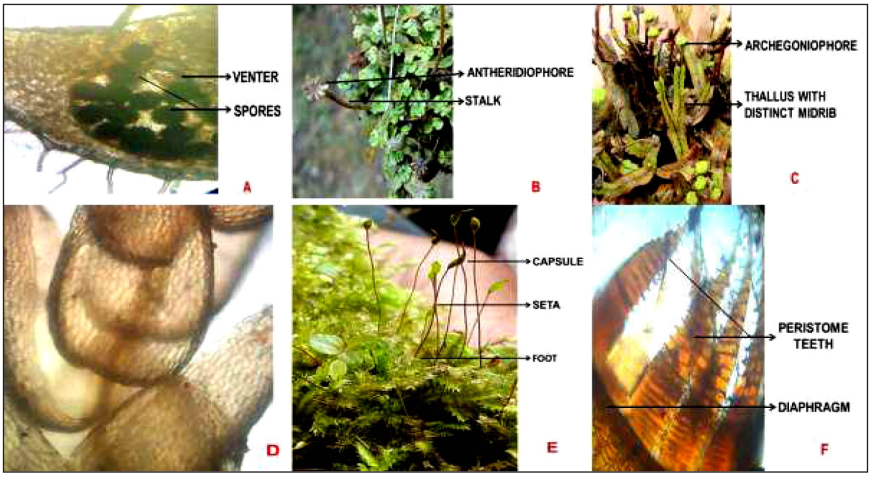

Fig. 2. Bryofloral diversity - Morphological and anatomical structures of different species of Bryophytes. Fig. A: Ventral transverse sectional view showing sporophyte with matured spores embedded within the thallus of *Riccia* sp. 40x (Ricciaceae) **Fig. B:** Male plants bearing antheridiophore of *Marchantia* sp. (Marchantiaceae) **Fig. C:** Female plants bearing archegoniophore of *Marchantia* sp. (Marchantiaceae) **Fig. D:** Surface view showing hyaline cells of young leaves of *Sphagnum* sp. 60x (Sphagnaceae) **Fig. E:** Photograph showing general structure of moss sporophyte bearing foot embedded in thallus, seta and capsule **Fig. F:** Longitudinal sectional view showing diplolepideous, epicranoid peristome teeth (having both outer and inner peristome teeth) of *Funaria* sp. 60 x (Funariaceae).

inner peristome and the outer peristome is superimposed on the latter i.e., epicranoid. The hygroscopic movement of the outer peristome teeth helps in the dispersal of the spores in presence or absence of moisture.

3. Bryofloral Distribution

Bryophytes being the second largest group of plants, form an integral component of tropical and temperate forests where they laid themselves down as carpets on the humid soil, boulders, living and dead logs and even hang from tree branches. Both the microclimatic factors such as rainfall and temperature, latitude and altitude (Sveinbjörnsson and Oechel 1992) and micro environmental conditions like shade, humidity, humus and temperature (Alpert, 1991) affect the distribution of bryophytes. Besides these, age of the soil, rocks, composition of forest soil, moisture content (Sillett and Neitlich 1996), pH and humus status (Batty *et al.* 2003) may also affect the bryofloral vegetation. In 2005, about 2480 taxa of bryophytes (including intraspecific taxa) are reported from India (including island groups, and Sikkim), comprising about 1623 taxa in 342 genera and 57 families of mosses, 36 taxa in 6 genera and 2 families of hornworts and about 722 taxa of liverworts in 128 genera and 52 families. According to the last updated checklist as provided by Dandotiya *et al.* (2011), the bryophytes are represented by about 2489 taxa comprising of 1786 species that includes 675 species in 121 genera of liverworts, 25 species in 6 genera of hornworts and 355 genera of mosses. Very few, selected and common bryophytes along from these three groups found in various places in India are provided in tabular form in Table 1.

Table-1: The table enlists few selected and common bryophytes from three groups found in various places in India (adapted from Dandotiya *et al.*, 2011).

Group	Serial No.	Species	Family	Distribution in India
L	**1.**	*Marchantia nepalensis* Lehm. & Lindenb.	Marchantiaceae	Outer Himalaya up to Kashmir Garhwal, Kumaon, Punjab plains, Nagaland
I	**2.**	*Marchantia paleacea* Bertol.	Marchantiaceae	Assam and Southern India, Himachal Pradesh, Jammu and Darjeeling, Sikkim.
V E	3.	*Marchantia palmata* Reinw. *et al.*	Marchantiaceae	Kumaon Himalaya and Outer Himalaya up to Kashmir, Kolkata, Assam, South India.
R	4.	*Marchantia polymorpha* L.	Marchantiaceae	Tamil Nadu, Jammu and Kashmir, Darjeeling, Sikkim, Assam, Rajasthan, Nagaland.
W	5.	*Riccia fluitans* L.	Ricciaceae	Garhwal, Kashmir, Mumbai, Assam, Himalayas, Kumaon, Pachmarhi, Western Ghats.
O	6	*Ricciocarpus natans* (L.) Corda	Ricciaceae	Kashmir, Dal lake, Guwahati, Manipur, South India, Eastern and Western Himalaya.
R	7	*Lunularia cruciata* (L.) Dumort. ex Lindb.	Lunulariaceae	Himalaya, Darjeeling, Kumaon Shimla, Chennai.
T	8	*Asterella khasiana* (Griff.) Grolle	Aytoniaceae	Nilgiri hills, Tamil Nadu, Nainital, Dalhousie, Darjeeling, Assam, Kolkata, Punjab.
S	9	*Plagiochasma appendiculatum* Lehm. & Lindenb.	Aytoniaceae	Nilgiri hills, Tamil Nadu, Nainital, Dalhousie, Darjeeling, Assam, Kolkata, Punjab.
	10	*Dumortiera hirsuta* (Sw.) Nees	Dumortieraceae	Nilgiri hills, Palni hills, Chennai, Tamil Nadu.
	11	*Pellia epiphylla* (L.) Corda	Pelliaceae	Himachal Pradesh, Sikkim, Darjeeling, Western Himalaya.
	12	*Porella campylophylla* (Lehm. & Lindenb.) Trevis.	Porellaceae	North West Himalaya, Darjeeling, Sikkim, Kerala, Tamil Nadu.

Group	Serial No.	Species	Family	Distribution in India
H	13	*Phaeoceros himalayensis* (Kashyap) Prosk. ex Bapna & G.G. Vyas	Anthocerotaceae	Kumaon Himalayas, Dehradun, Mumbai
O	14	*Anthoceros crispulus* (Mont.) Douin	Anthocerotaceae	Kodaikanal, W. Himalaya, E. Himalaya, Kerala, Tamil Nadu Ooty, Naduvattam
R	15	*Folioceros glandulosus* (Lehm. & Lindenb.) D.C. Bharadwaj	Anthocerotaceae	Sikkim
N	16	*Notothylas himalayensis* Udar et Singh	Notothyladaceae	Mussoorie, Punjab, Rajasthan, Himachal Pradesh
W	17	*Notothylas indica* Kashyap	Notothyladaceae	Madras, Himachal Pradesh, Dehradun, Allahabad, Mumbai, Nagpur
O **R**	18	*Notothylas levieri* Schiffn. ex Steph	Notothyladaceae	Himachal Pradesh, Kumaon Himalayas, Shimla, Mussoorie, Sikkim, Wayanad, Central Himalaya, Palakkad
T	19	*Phaeoceros carolinianus* (Michx.) Prosk.	Notothyladaceae	Himachal Pradesh, Uttarakhand, Darjeeling, Arunachal Pradesh, Madhya Pradesh, Punjab.
S	20	*Phaeoceros laevis* (L.) Prosk.	Notothyladaceae	Darjeeling, East Sikkim, Arunachal Pradesh, Meghalaya, Tamil Nadu, Kerala, Nilgiris, Himachal Pradesh
	21	*Megaceros tjibodensis* Campb.	Dendrocerotaceae	Himachal Pradesh
M	22	*Sphagnum khasianum* Mitt.	Sphagnaceae	Khasia hills, Assam, Manipur, Sikkim, Darjeeling
	23	*Atrichum longifolium* Cardot & Dixon ex Gangulee	Polytrichaceae	Darjeeling, Kolkata, South India, Eastern India
	24	*Lyellia cripsa* R. Br.	Polytrichaceae	Darjeeling, Sikkim, Arunachal Pradesh
O	25	*Pogonatum aloides* (Hedw.) P. Beauv	Polytrichaceae	Darjeeling, Sikkim, Shimla, Mussoorie, Garhwal, Tamil Nadu (Haduvattum)
S	26	*Entosthodon nutans* Mitt.	Funariaceae	Chhotanagpur, Gangetic, Howrah, Hooghly, Punjab, U.P, Jaipur, Tehri, Hindolakhal
	27	*Funaria hygrometrica* Hedw. var. *calvescens* (Schwagr.) Mont.	Funariaceae	Himalaya, Eastern and Western Ghats Manipur, Arunachal Pradesh, Orissa, Kerala.
	28	*Grimmia elongata* Kaulf.	Grimmiaceae	Sikkim
S	29	*Fissidens bryoides* Hedw.	Fissidentaceae	Khasia hills, Kolkata, Ranikhet, Shimla, Western Ghats, Nilgiris
E	30	*Bryum alpinum* With.	Bryaceae	Sikkim, Darjeeling, Khasia hills, Manipur, Shimla, Kashmir, Nilgiri hills
	31	*Mnium rostratum* Schrad.	Mniaceae	Sikkim, Darjeeling , Arunachal Pradesh, Khasia hills, Assam, Kashmir, Nilgiri hills.
S	32	*Taxithelium nepalense* (Schwagr.) Broth.	Sematophyllaceae	Garo hills, Kolkata (Howrah, Hooghly, Nadia), Orissa, Nicobar, E. Himalaya, S. India

Group	Serial No.	Species	Family	Distribution in India
	33	*Pinnatella calcuttensis* (C. Muell.) Fleish	Neckeraceae	Bengal, Darjeeling, Orissa, Karnataka, Kerala, Mahabaleshwar
	34	*Thamnium siamense* Horik. & Audo	Neckeraceae	Assam
	35	*Grimmia elongata* Kaulf.	Grimmiaceae	Sikkim

Various workers reported the distribution of bryophytes in various places of India. Dash *et al.* (2009) reported 31 Species of bryophytes including 20 liverworts, 2 hornworts and 9 mosses under 17 families and 22 genera for the first time from the Bothamalai hills in the Eastern Ghats of India. The checklist provided by Daneils (2010) showed that Tamil Nadu supports approximately 29 % of the Indian liverwort flora of which 152 liverwort taxa are endemic to India (including all island groups and Sikkim). Alam *et al.*, (2011) reported the current status of mosses from Palnihills confirming the presence of 54 taxa in Kodaikanal and neighbouring areas of which 12 taxa are new to the Palni hills indicating the potentiality of this region in nourishing the bryofloral diversity. Sharma and Choyal (2011) reported 9 species of mosses after studying the distribution of moss in the topography of Kangra district of Himachal Pradesh. Barukial (2011) has worked on the taxonomic enumeration of 127 species of mosses under 71 genera belonging to 27 families from the Assam Valley Wet Evergreen forests, Assam. Rawat *et al.*, (2016) has provided an updated account of 79 taxa of mosses with 19 families and 40 genera in and around Gangetic plains.

3.1. Bryofloral synecological societies with reference to special habitats

Synecological studies refer to studies involving different communities and societies in relation to the ecological conditions such as water, temperature, light and edaphic factors. Bryophytes keeps themselves restricted to certain habitats such as bare rock surface, bark of trees, decomposed logs and stumps, damp forest floors that provide suitable moisture and humus and pH. Moss carpet on the forest floor provides an ambience for higher plants to germinate their seeds and growth of their seedlings.

The following synecological societies are enlisted below

(i) **Aquatic bryophytes** - Very few species such as *Riccia fluitans, Ricciocarpus* in India are floating not fixed by rhizoids.

(ii) **Saprophytic bryophytes** – *Cryptothallus* and *Buxbaumia* generally grow on dead and decaying organic matter. *Cryptothallus* are chlorophyll-less absorbing nutrients from their symbiotic partner mycorrhiza.

(iii) **Epiphyllous bryophytes** – Some species of bryophytes grows on leaves of which *Lejeunea* in the eastern Himalaya are very common.

(iv) **Epiphytic bryophytes** – These bryophytes inhabit bark of trees, twigs, branches and fissures for their establishment along with moisture availability and humus content. These epiphytic bryophytes thrive in wet tropical rainforests where there are plenty of nutrients and moisture is available. These luxuriant forms of mosses form a lovely site in dense forest areas that create a good environment for these lower plants.

(v) **Epixylic bryophytes** – Most pleurocarpic mosses form a carpet on dead rotten logs and wood in humid forest are epixylic bryophytes. Some acrocarpous mosses like *Stereophyllum, Syrrhopodon* grows in tree barks as well as thalloid and foliose hepaticopsids namely *Aneura, Reboulia, Riccardia, Symphyogyna* also appear on dead wood. Harmon *et al.*, (1986) demonstrated the ecological importance of these bryophytes that provides a suitable habitat for various organisms, source of minerals and ultimately influencing soil deposition. These bryophyte communities participate in the successional alternations in the physiochemical properties during its decay i.e., change in texture, density of wood, pH as well as water holding capacity (Crites and Dale, 1998; Vellak and Paal, 1999). Heilmann-Clausen and Christensen, (2003) considered some important factors like dead tree decay stage, species of the tree, trunk dimension and the microclimate are required for the establishment of such communities.

(vi) **Saxicolous bryophytes** – These bryophytes grow exclusively on rocks and have shown its capability to adapt according to specific requirement perhaps for a permanent habitat. These plants can survive in water deficit conditions and have potential to grow on such firm substrates. Some saxicolous bryophytes are *Porella platyphylla, Grimmia* sp., *Gymnostomum* sp., *Tortella* sp.

(vii) **Coprophilous bryophytes** – Members of the family Splachnaceae are adapted to inhabit in nutrient deficient condition and grow on decomposed animal excreta.

(viii) **Xerogeophytic bryophytes** - These bryophytes colonize and complete their life cycle on sand where the plant combats with water stress along with high temperature stress during daylight. They are buried in the soil during unfavourable conditions and reappear as well as revive after few showers of rain. Members of family Marchantiaceae, Pottiaceae, Grimmiaceae, Bryaceae etc. belong to this synecological society. Bryophytes such as *Sphagnum* absorb water within no time and retain the water for long time even when they are dried in unfavourable conditions and therefore named as 'Resurrection plants'.

4. Bryofloral members cross talks with members of animal kingdom

One of the very interesting areas of biological science is the plant-animal interactions. These interactions become important to such an extent that either plant or animal becomes obligatory dependent on each other to complete their life cycle. Gressitt *et al.* (1968) reported some bryophytes namely *Metzgeria, Microlejeunea, Cololejeunea, Daltonia angustifolia* and *Odontolejeunea* to live on the backs of certain weevils like *Gymnopholus* (genus of beetles) in humid tropical forests. Some insects help in spore dispersal from mature sporangium to a nitrogen rich substratum where this spore can germinate into a new plant body. The growth forms of bryophytes such as *Herbertus* and *Frullania* have provided home to many invertebrates especially rotifers and nematodes. This in turn helps in mineral cycling thereby promoting growth of the vegetation. These invertebrates play an important role in bringing genetic variations among species promoting cross pollination by transferring antherozoids from antheridia of one plant body to the egg of archegonia of another plant body. This helps the bryophytes especially the coprophilous ones with spore dispersal. Cronberg *et al.*, (2006) demonstrated that fertilization in moss *Bryum argenteum* by the microarthopods mainly spring tales and mites. Spiders, ants, mites make their shelter within mosses and that too snails also find aquatic mosses as their best habitat for laying their eggs. Rosensteil *et al.*, (2012) demonstrated the improvement in fertilization by springtails even in presence of water and also identified certain volatile chemicals from fertile shoots that attracted the springtails more towards the fertile shoots. These reports draw attention towards pollination syndrome that can be compared with insect pollination in angiosperms. Even many birds use pleurocarpic mosses for the construction of their nests because of their light weight as compared to other vegetation.

5. Bryo-ecological perspectives with special reference to desiccation stress tolerant species

Bryophytes adapted themselves in their respective habitats based on the ecological factors such as water, temperature, light, soil required for their sustenance in the nature. They play important roles in maintaining the ecological balance by trapping nutrients, stabilizing soils and acting as soil binders; by water retaining capacity at the time of desiccation stress; forms moist mat on the forest floor that provides an advantage for the seeds of higher plants to germinate. Bates (1990) pointed out an additional role of bryophytes in maintaining forest ecosystem by self-filtering of water through the cation exchange system. The bryophytes in association with cyanobacteria are capable of fixing nitrogen and have the capability to adding nutrients and humus to the soil by converting rough surfaces and promoting colonization of new species. With the gradual process of succession results in the establishment of higher plants. Even a barren rock covered with soil provides an opportunity to the bryophytes to colonize in For example, moss *Bryum* has an exceptional quality to grow fast and colonize in the soil.Bryophytes are referred to as indicator plants because of the ability of certain bryophytes to determine the chemical nature of substratum in which they grow. Copper moss, *Merceya* thriving in the Himalayas indicates the presence of copper in the substrata. Sala *et al.* (2000) demonstrated the ability of living cells of *Sphagnum* thalli to accumulate nutrients directly from the atmosphere. Bryophytes apart from evaluating metal ions in substratum, also possess the capability to act as indicators for evaluating human intervention in forests (Vellak and Paal, 1999). Linkola (1916) used the term 'hemerophobic sensu' to indicate those bryophytes that cannot survive in the area with any kind of human interventions such as forest cutting or drainage. This gave an idea of some bryophytes species that may survive in the forest with no human interference (Cooper-Ellis 1998).

Water plays an important role in the life of amphibians of plant kingdom because without this important resource bryophytes cannot complete their life cycle. However, nature has gifted bryophytes with special talent of tolerating desiccation stress as compared to other plants. During water stress conditon, bryophytes combat this situation by their water holding capacity and revive themselves resuming photosynthesis and respiration within few hours when water becomes available. *Tortula ruralis* have the ability to tolerate stress upto ten months and then revive itself soon within few hours of rehydration. The youngest part of *Tortula* has that capability of tolerating low temperature. Another moss *Andreaea rothii* has the ability to revive its photosynthetic machinery even after 12 months of desiccation stress. Drought tolerant species are of two types namely poikilochlorophyllous and homoiochlorophyllous. The mosses prevent water loss with the help of cuticle and by changing the morphology of leaves and branches. Oliver *et al.*, (2000) pointed the desiccation stress tolerance as a primitive character. This shows that bryophytes have significant physiological adaptive ability to down-regulate their metabolism at the time of desiccation stress which again possesses the ability to up regulate its own metabolism within few hours of rehydration.

6. Need for the conservation of these amphibian members of plant kingdom

Nature that produced these beautiful bryoflora is constantly facing danger from the human activities resulting in the deterioration of their natural habitat. Man always crave for more and this has led to the threatening of these lower groups of plants and transform large forest areas to frame agricultural lands, rehabilitation, factories, roads, dams etc. All these human activities are leading to the loss of bryofloral biodiversity. Human induced global warming increased the global temperature all over the world disturbing the microclimate of the bryophytes thereby responsible for the loss of bryophytes. Natural forest fires or human induced forest fires often affects the growth of the bryophytes. Besides the above causes, pollution from industrial belts and urban areas also contribute to the loss. Foresters often study bryophytes as a tool to determine the condition of the land. Therefore bryophytes can be used as bryometers for measuring phytotoxic air pollutants. Hilton-Taylor (2000) reported that 42 species of Hepaticopsida, 2 species of Anthocerotopsida and 36 species of Bryopsida have become threatened species and 1 species of Hepaticopsida and 2 species of Bryopsida have become extinct. Overall, anthropogenic activities, global warming, land use change, exotic species invasion, creation of dams, forest clearance are posing serious threat to the bryofloral biodiversity. Large amount of mosses are illegally extracted from forests of Himalayas for various purposes. For these reasons, conservation strategies are required to protect the large natural reserves that are constantly facing threat.

7. Concluding remarks with reference to prospecting of bryophytes

Many Indian bryologists have reported that enough focus is not given in bryofloral study and there remains a lacuna in the field of bryological research. The probable reasons for lacuna in this research area may be due to lack of expert bryologists, few laboratories with good facilities, lack of proper taxonomic enumeration of bryological species with no herbarium records, lack of available literatures and lack of students with potential interests to work with bryophytes. The bryophytes has occupied an interesting place in plant biology books for imparting only knowledge but scientists as well as students need to rejenuvate this area by working practically with biotechnological applications of bryophytes for extraction of potential phytochemical compounds that have potential pharmaceutical and pharmacological uses to be used as drugs. Many universities in abroad are investigating new drug candidates from bryophytes to treat rare human diseases. The scope of bryological research in India has decreased due to lack of proper sufficient funds. Recent advances in the area of genomics, proteomics and natural product chemistry have showed the potentiality of bryophytes to produce bioactive phytochemicals that function within the host and environment. The world of bryophytes is a rich source for exploitation as it provides an interesting, fascinating and almost endless source of biological diversity.

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