Biodiversity of Amphibian Plants: Role of Water in Colonization and Community Structure of Bryophytes

Ajit Pratap Singh and P. B. Khare

Pteridology Laboratory, CSIR-National Botanical Research Institute,
2-Rana Pratap Marg, Lucknow-U.P.,-India
Email: ajitpsingh2000@gmail.com

Introduction

Bryophytes are non-flowering, cryptogrammic group of plants which preferentially grow in moist, shade, cold and tropical regions of the world. They contribute to ecosystem management and sustainability of environment in addition to various value added research and developmental activities. Bryophytes exhibit two phases in their life cycle—the gametophyte and sporophyte.

The gametophyte (dominant phase) is autotrophic whereas the sporophyte is completely or partially dependent (heterotrophic) on gametophyte. The gametophyte stage begins once meiotic division occur in sporogenous cells of the short lived sporophyte. Meiosis and mitotic division led to develop number of haploid spores per capsule. During division, few of the cells become sterile in scarcity of the nutrition and tend to form the elaters. Elaters may be elongated, simple with spiral thickening bands (liverworts) or ambiguous, branched and stumpy (hornworts). For the reason of their hygroscopic nature elaters perform significant role for dispersal of the spores at maturity of the capsule. These elaters disperse the spores at variable distance and play significant role for establishment, colonization and distribution pattern of population and community structure of bryophytes across the regions.

In the beginning, spore content turned chlorophyllous and develops into single or two celled protonema. One or more hyaline simple or tuberculate rhizoid (s) develops from the basal region of these cells. These chlorophyllous cells mature either into cordate thallus (thalloid liverworts and hornworts) or leafy bryophytes (leafy liverworts and mosses). Mature gametophytes bear both male and female sex organs on same (monoecious) or different gametophytes (dioecious). Both the gametes (male and female) demeanour fertilization in presence of water and produce sporophytes.

It is fascinating to notice that every species of the bryophyte require water in their sexual stages of life cycle to perform gametic fusion. For the reason of their habit to grow in both the aquatic as well as terrestrial habitat, they are also called the amphibian plants. Thus, the life cycle of a species of bryophyte involve various stages of development, which require numerous abiotic factors for their growth and developmental pattern. Amongst these abiotic factors, the water and combination of various substrates have vast impact on the colonization potential of bryophytes in different gradient of habitat and ecosystem.

Why be concerned about Bryophytes?

It is perceived that every component (biotic and abiotic) on this globe has their active and passive role to sustain the environment. Contributions of small organisms including bryophytes, their diversity or their role in establishing diversity of other living organisms are less known. Now, it is realized that bryophytes having the second or third position in plant diversity status may have a major role in water retention, water availability and nutrient cycling.

Majority of the species of bryophytes give a clue to the evolutionary history of the plants. The genomic and proteomic studies also have open opportunity to understand genetic regulation of many biochemical processes including discovery of new genes and proteins as well. The global warming problem is another discipline where the bryophytes are playing significant role. Bryophytes are very sensitive to changes in environment thus are helpful to monitor and mitigate the environmental issues on the globe. Bryophytes, mainly peat mosses cover 2% of the earth surface and make substantial contributions to the vegetation of earth. It is realized that little is known about bryophytes and there should be an immediate approach to prospect the diversity, manage and utilize bryophytes sustainably.

Habitat Specificity in Bryophytes and Role of Water

The abiotic factors including water, light and substrates determine their occurrence, quantity and spatial arrangement. Population size and community structure of bryophytes is related by the combination of ambient environment. All these factors collectively decide fate for co-existence of variable species in the community and the maintenance of population and community itself through time in available ecological resources. Thus, bryophytes are quite unique in their habitat specificity and microclimatic niche that form the variable composition of bryophytes diversity from ground to canopy or emergent vegetation.

In the tropical rain forests they cover ground and form huge ground vegetation, or growing on rocks form saxicolous vegetation, growing on other plants form epiphytic vegetation or growing in or around water bodies form aquatic vegetation. In all the aspects, they require plenty of water in form of drop, vapour or snow. Depending upon the availability of water in surrounding areas bryophytes absorb it either through rhizoids or conductive strands and translocate to plant. More preferably they absorb it throughout the plant, because the plants are noncuticularized and are capable to absorb water and other minerals through shoots and leaf. The water is available across the globe from sub-tropical dry deciduous forests to polar region in form of water, vapour or snow. Therefore, bryophytes invade any geographical region and form quite variable and interesting vegetation. Evolution of bryophytes, diversity status, the vegetation cover, water relation, population, community structure and colonization potential are briefly mentioned.

Evolution of Bryophytes Diversity

Since the very beginning of evolution of life in form of the simplest coacervates and unicellular organisms, water was invariably involved in block building of individual organisms on earth. The hypothesis of biochemical origin of life involved four life gases (carbon, hydrogen, nitrogen and oxygen) that eventually led to diversify living organisms in water bodies. Thus, water became an ultimate medium for evolution and survival of living organisms.

Majority of the cyano-phycean, chlorophycean algae (unicellular and multicellular) evolved in water bodies. For the reason of nutritional competition, algae inclined towards land and adapted terrestrial habitat (*Colecochate* sp., *Freistiella* sp.) that shown much affinity with hornworts. In the evolution of plants, bryophytes have long history and known for their earliest record in Devonian period of the late Palaeozoic era. The fossil records of *Metzgeriothallus sharonae* from the Givetian (Upper Middle Devonian) shales and *Pallaviciniites* (=*Hepaticiites*) devonicus from the Upper Devonian of New York (Hueber, 1961) has shown their occurrence in Palaeozoic era. In this way the bryophytes have valuable importance to unearth the number of uncertain hypothesis of their evolution through ages. They may also serve as valuable organisms for prospecting their relation with water in oldest periods. Various species of *Pallaviciniites* have been described from Carboniferous to the Pleistocene and they have been compared with such living genera *Pallavicinia, Metzgeria, Treubia*, and *Fossmbronia* (Schuster, 1966). Fossil records indicated that the bryophytes which are surviving through ages were the primary and major component of plant diversity in the oldest period.

Biodiversity of Amphibian Plants (Bryophytes)

Biodiversity refers to total variability amongst living organism in a particular space at particular time. The degree of variation amongst living organisms occurs at species, genus, ecosystem and biome or planet level. The degree of diversity in bryophytes at variable gradients of habitat is quite significant. On the basis of diversity in morphological and structural attributes they are categorised into ***liverworts, hornworts*** and ***mosses***. Previous postulation concurred that the divergence in species and their genus occurred in the progenitors of aquatic habitat. Amongst different land dwelling plant groups (algae, fungi, lichens, bryophytes, gymnosperms and angiosperms) the angiosperms stand on top in the species number (± 2.5 lac) and biomass composition. Bryophytes are equally significant and play an important role in biodiversity structure and plant biomass. In the terrestrial habitat, bryophytes stand next to angio-sperms in their species composition and ecological significance.

Majority of the species of bryophytes are terrestrial nevertheless the aquatic species are not uncommon. They grow in the vicinity of water because it acts as medium for the movement of antherozoids during sexual fusion in gametophytic stage. Every species of the bryophyte needs water in either of their stages of life cycle, but it is necessarily required in sexual stages to perform gametic fusion. Many of the bryophytes, such as *Ricciocarpus natans* and *Riccia fluitans* were known to grow into aquatic habitat. These primitive and water inhabiting bryophytes were such a simple in morphology and structure. Adaptation to terrestrial habitat eventually diversified their form and structure which consequence various representatives of present days Marchantiales. As a result, many of the species of *Riccia, Marchantia* (Fig. 1-A), *Plagiochasma* (Fig. 1-B), *Fimbriaria* (Fig. 1-C), *Fossombronia* (Fig. 1-D) evolved with complexity in their structure. Individual sporophytes which were initially comprised of oval capsule (*Riccia* sp.) developed foot and elongated seta (*Marchantia* sp., *Pellia* sp.). This seta later developed in to conductive strands as in many thalloids of present day *Metzgeriales* including *Pallavicinia* sp. (Fig. 1-E). It was also observed that in certain bryophyte including *Anthoceros* (Fig. 1-F) and *Notothyllus*, the columella continue elongation downward that led to vascularise the plants, but interestingly the single pyrenoid chlorophyll show its proximity with algae. Conductive strands became prominent and efficient as a result many of the plant species adapted water scarce regions. This led to evolve various form of mosses. Amongst these mosses, the species of *Takakia, Sphagnum, Andrea, Polytrichum, Hyophila* (Fig. 2-B), *Tetraphida, Buxbamia, Diphyscia, Physcomitriella, Bryum* (Fig. 2-A) etc developing conductive strands (leptoids and hydroids) behave invariably and comprised rich plant diversity next to flowering plants. Altogether the liverworts including thalloid and leafy comprises two major groups—*Marchantiopsida* and *Jungermanniopsida*. The *Marchantiopsida* is broadly divided into two subclasses—*Sphaerocarpidae* (Sphaerocarpus) and *Marchantiidae* (*Riccia, Marchantia, Monoclea*), however the Jungermanniopsida is categorised in to two subclasses—Metzgeriidae (*Haplomitrium, Blasia, Treubia, Fossombronia, Metzgera*) and Jungermannidae (*Lepicolea, Jungermannia, Lejeunea, Porella, Radula, Pleurozia*). The hornworts representing single class Anthocerotopsida are represented with Anthoceros, Phaeoceros, Notothylus. Similarly, the mosses by their diverse form and morphology are categorized into 5 major classes—Takakiopsida (*Takakia*), Sphagnopsida (*Sphagnum*), Andreopsida (*Andrea*), Andreaeobryopsida (*Andreaeobryum*), Polytrichopsida (*Polytrichum*), Bryopsida (*Bryum*).

Altogether, bryophytes are represented with about 18 orders, 111 families, 889 genera and approximately 14,000 species (Groombridge, 1992; Nayar, 1996). In India they are represented with approximately 2600 species including 873 liverworts, 33 hornworts and 1694 mosses (Parihar *et al.*, 1994; Lal, 2005; Singh and Nath, 2007). Study on diversity and distribution pattern of the bryophytes revealed that many of species were growing in thin population with few individuals or few of them were represented as monotypic. The *Takakia ceratophylla*, which was earlier considered under

Fig. 1 (A-F) : **A.** *Marchantia papillata* ssp *grossibarba*, **B.** *Plagiochasma appendiculata*, **C.** *Fimbriaria* sp., **D.** *Fossombronia* sp., *E. Pallavicinia*., **F.** *Anthoceros* sp.

liverworts (but now mosses), was known from single locality in India (Mitten, 1860-61). Similarly, the *Jungermannia sikkimensis* was extremely rare in Sikkim but shown its extended range of distribution in Meghalaya (Singh and Nath, 2007). The *Aichinsoniella himalayensis, Sewardiella tuberifera* and *Stephensoniella brevipedunculata* were known as monotypic and reported from few of the localities in western Himalayas

(Kashyap, 1929; Kashyap, 1932; Kashyap and Chopra, 1932). No repetitive collection of these monotypic taxa was made and also their population are at high risk of extinction. Henceforth, they are also categorized under Red Data Book. Studies on bryophytes have discovered many new species from Himalayas. Few of the newly discovered species of bryophytes were: *Frullania udarii* (Nath and Singh, 2006) *Trocholejeunea meghalayensis* (Singh and Nath, 2008), *Drepanolejeunea longifolia*, *Drepanolejeunea mawtmiana* (Singh *et al.*, 2008).

Bryophytes preferentially grow in moist, rain forest regions of the globe, therefore in India the Himalayas and mountainous regions of southern India are suitable geographical region for their growth and occurrence. The seven sisters (Assam, Meghalaya, Manipur, Mizoram, Tripura, Arunachal Pradesh, Sikkim) in North Eastern Himalayas; the western Ghats in southern India, western Himalayas are adobe for these tiny plants. The mountainous regions of central India including Satpura and Vindhya ranges are not uncommon to harbour their natural habitats. Thus, few of the representatives of these hot spots also grow under the plentiful resources of dripping water on rocks or crevices of steep rocks.

Vegetation Cover of Bryophytes and Role of Water

As soon as the spore bearing capsules of bryophyte dehisce by hygroscopic (absorption of water) nature, the spores are shed and thrown on variable substrates. These substrates co-exhibiting microclimatic conditions widen environmental amplitude. Similarly, the fragmentation of their vegetative parts (gemmae, protonema, propagules and brood bodies) is also thrown on these substratums. The water (droplets, humidity and snow) present in the air, crevices of rocks, streams, capillary of soil etc provide moisture to spores and these vegetative propagules. Due to lack of cuticular covering on the vegetative propagules, water is absorbed. These absorbed water triggers the receptor protein to instigate circadian biochemical pathway for physio-biochemical activities, wherein the protoplasm gets stimulated to perform vitality and further activities. In addition to water, simultaneously whole of the vegetative propagule meet out their nutritional demand from the surroundings. It is only because the exterior cells of bryophyte exhibit some active moidies and receptor proteins, which binds the nutrients present in ambient atmosphere. These nutrients are passing on inwardly to the molecules involved in biochemical pathways of metabolism. In this way the bryophytes start multiplying on the substrates and survive for prolonged period. They form a thick covering on substrates producing multiple individual, their population and community structure. For the reason of habitat specificity they form different vegetation cover across the globe, few of them are mentioned below.

Ground Vegetation of Bryophyte

Ground vegetation is promoted by the availability of water and nutrients in the area. The ground profile is usually comprised of the soil, humus, litter, clay, silt, morang, carbonates of salts and many micro and macro-elements. For these tiny plants the water resources are mainly rain water or capillary water running through the ground profile (Fig. 2-C). The humidity, atmospheric pressure and temperature have significant role to make water available for them. Individual species growing on the ground absorbs capillary water running through ground by the lowermost part of the plants (rhizoids, vegetative parts). A channel of water from the capillary of soil up to the plants interior tissue is maintained to keep continuousness in their vitality. Lobules and amphigastria in the plants serves as water reservoir to make it available whenever needed. Water is also stored in the capillary, intercellular and intracellular spaces of the plants, which however are needed during physio-biochemical activities. For the enrichment of ground vegetation, individual species absorbs water from substrate (soil, rock, humus and litter) and increases their population by sexual and vegetative mode. The ground vegetation is mainly comprised by the species of thalloid liverworts—*Marchantia, Plagiochasma* (Fig. 2-D); hornworts—*Phaeoceros, Anthoceros* (Fig. 1-F); and mosses—*Atrichum, Bryum* (Fig. 2-A). Thus, the ground vegetation of bryophytes, population and community structure on soil substrate is more distinct that also maintains the water balance in ecosystem.

Saxicolous Vegetation of Bryophyte

Bryophytes are very distinct from other organisms as they can absorb water from ambient environment. In saxicolous habitat, they usually prefer to grow either on

Fig. 2 (A-F) : A. *Bryum* sp., **B.** *Hyophila* sp., **C.** *Aquatic and saxicolous habitat of Bryophytes,* **D**. *Plagiochasma appendiculata,* **E.** *Anthoceros* sp., **F**. *Epiphyllous* habitat of moss.

rocks, soil covered rocks, on weathered or on the rocks which are in the process of weathering (Fig. 2-E). It is for the reason because they get the required elements from these rocks for their growth and development. Rocks are usually comprised of silts, sands, macro and microelements, which are the basic need of bryophytes during mineral intake. Over the range of mountains, the rocks get covered with green vegetation of bryophytes during the rains. The species of *Riccia, Conocephalum, Anthoceros, Radulla, Frullania, Lejeunea, Riccardia, Scapania, Meteoriopsis* and *Bryum aregentium* (Fig. 3-B) are common bryophytes which preferentially grow on the rocks forming saxicolous vegetation. In the beginning, bryophytes absorb nutrients from the rocks which in long term uses become nutrient deficient. Thus, they secrete chemicals which chelate the rocks in to small pieces and simple micronutrients. This makes availability of nutrients for luxuriant growth and development of bryophytes on rocks. The dripping water, moisture or water stored in the rock layers play significant role for chelating the complex nutrient compounds. By subsequent death, decay, fragmentation and re-juvenation of bryophytes, the rocks are weathered and a vegetation cover is formed over the rocks.

Epiphytic Vegetation of Bryophyte

Bryophytes are very sensitive to microclimate and require specific ecological niche for their growth and development. In the tropical rain forests, evergreen forests and tropical dry-deciduous forests, the ground vegetation is also occupied with the higher plants. The higher plants provide variable microclimatic condition to these tiny plants hence they are also called phorophytes. These phorophytes provide shelter to bryophytes on their root, stem, bark ridges and furrows, branches and leaves (Fig. 2-F). The basal portions of tree trunk usually are in contact with the soil, humus and ground water, hence suits for the growth and development of some thin thalloid liverworts: *Metzgeria* sp., *Pallavicinia* sp. and mosses: *Rhodobryum* sp., *Bryum* sp. The stem or bark of phorophytes is usually smooth (*Ficus* sp.) or comprised of ridge and furrows (*Cedrus* sp., *Bauhinia* sp., *Mallotus philippensis*, *Mangifera sylvatica*). Smooth bark does not hold water so that they usually harbour species which require meagre amount of water from the substrate or atmosphere. These species (*Leptolejeunea* sp., *Cololejeunea* sp., *Harpalejeunea* sp., *Lophozia* sp., *Lophocolea* sp.) are smaller and microscopic. Because of their less area occupancy and meagre requirement of water, they grow on such substrate so that they may meet out it from the atmospheric humidity. In case of the phorophytes with ridge and furrow, there are spaces in the furrows from one ridge to another. These furrows co-exhibit efficient amount of water, nutrients (which are run off through entire bark and stored in furrows by rain water), cooling conditions, temperature and more particularly the essential amount of light. These factors altogether maintain a very specific microclimatic niche for spore germination and its maturation into gametophyte. Majority of the species of bryophytes including liverworts (*Lejeunea* sp., *Ptychanthus* sp., *Sprucianthus* sp., *Mastigolejeunea* sp., *Plagiochila* sp., *Herbertus* sp.) and mosses (*Pinnatella* sp., *Hypnum* sp., *Orthotrichum* sp., *Brachythecium* sp., *Dicranum* sp.) grow on the tree trunk of various phorophytes, where potentiality of colonization and community structure development of species and population is dependent on varied gradient of water availability. Leaf morphology of the phorophytes is quite variable from different gradients of altitude in any forest ecosystem. Abaxial side of the leaves are usually rough, which however is smooth on adaxial side. In some cases both the sides are smooth and rough. It has been often noticed that the leaf of phorophytes provide shelter for the liverworts and mosses (Fig. 2-F). Rough side of the leaves co-exhibit hairs and opening of stomata (door for intake and outlet of gases and elements) in very definite pattern, hence the water and elements are trapped in inter-hair spaces and near to stomata openings. Spores of certain liverworts (*Cololejeunea* sp., *Leptolejeunea* sp., *Cheilolejeunea* sp., *Radula* sp.) and mosses absorb water and elements from these spaces and forms colony and community of the bryophytes. Thus, in a forest ecosystem, the epiphytic vegetation can be gauzed from low land area to different gradient of altitude and also from the basal region of trunk to the canopy or emergent level of phorophytes.

Aquatic Vegetation of Bryophyte

Water and bryophytes have inherent interrelation. Although all of the bryophytes require water atleast at the stage of gamete fusion, but majority of them take it in active and passive form. The water bodies such as stream, lakes, brook and bogs are home to many species of liverworts and mosses (Fig. 2-C). Significant amongst the bryophytes are species of the *Sphagnum* growing in the proximity of water. They are estimated to cover approximately 2% of the world's land surface (more than the area covered by any other single plant genus) having significant ecological roles. It is noticed that the Sphagnum preferentially grow in watered areas. Continuous and consistent growth of the species forms Peatland, which are comprised of one or more species of

Fig. 3 (A-F) : A. *Dumortiera* sp., **B.** *Bryum argentium*, **C.** *Fissidens* sp., **D**. *Minium* sp., **E.** *Meteoriopsis* sp. growing on bark (epiphytic), **F**. *Lejeunea* sp. on wet soil.

Sphagnum. Peatland are usually formed on the prone region of bryophytes growth that can be distinguished by the lack of tree species and dominance of moss beds. It may be large, interrupted, and hummocky with occasional moss hummocks or moss bed floating on water. Thus, whole of the water bodies are covered with a thick (up to 20 metre) layer of mosses, which can bear a million of tons weight. In addition to peat mosses, many other species of bryophytes such as *Dumortiera* sp. (Fig. 3-A), *Brachythecium* sp., *Ambylostegium* sp., *Fontinalis* sp., *Palustriella* sp., *Cratoneuron* sp., *Fissidens* sp. (Fig. 3-C), *Cinclidotus* sp., *Leptodictyum* sp., and *Riccia fluitans* preferentially grow in aquatic habitat forming a vegetation cover on or around the water bodies. Many species involved in succession on water ecosystem do provide substrate for other invading species. The species of Sphagnum with other mosses initially grow on water bodies and form a thick layer. Successive death and decay of the bryophytes form substrata for other species which later develops into a vegetation cover on water bodies. It has also been noticed that many of the bryophytes do not require water always direct from the system. They meet out it through passive mode. In cold regions as snow cover is formed, the inhabiting bryophytes buried under thick layer of snow survive longer maintaining internal temperature to make availability of water.

Habitat Adaptation and Colonization Mechanisms in Bryophytes

Adaptive mechanism to terrestrial habitat led the plants to survive in scarcity of water, but the level of dependency on water and survival success became quite variable in different group of plants. In case of bryophytes, surviving to water scarcity and prolonged exposure of drought was an essential need to survive in traumatic circumstances. To withstand in those circumstances they devised physiological mechanism some 450 million years ago in Palaeozoic era (Proctor, 2000; Oliver *et al.*, 2000). Studies shows that many bryophytes are vascular, but they lack lignin (associated with cellulose in cell walls of sclerenchyma, xylem vessels, tracheids) and the variety of perforated and spirally thickened cells typical of xylem. Bryophytes exhibit unique cells that perform conduction in different ways from that of the true vascular plants. Land invading plants including algae (*Colecochate* sp., *Freistiella* sp.), bryophytes (*Lejeunea* sp., *Anthoceros* sp., *Bryum* sp.), pteridophytes (*Hymenophyllum* sp.), gymnosperm (*Cedrus* sp., *Ephedra* sp.), angiosperm (*Opuntia* sp., *Casurina* sp., *Delbergia* sp., *Trapa* sp.) require water in variable quantity. But, the quantity of water becomes an intrinsic need for any of the species of bryophyte, their population development, community structure and in total diversity in variable ecological regions including aquatic, terrestrial, cold etc on the globe.

The colonization potentiality and community structure of bryophytes depends on availability of water across different gradient of altitude in subtropical to polar region. Colonization also depends on number of environmental factors including light, temperature, moisture, humidity, water vapour, water drop, snow cover, nutrients availability and atmospheric pressure. Depending on the availability of these factors across different gradient of altitude in subtropical to polar region bryophytes colonize themselves and form population and community structure. Dependency of bryophytes is closely connected with light and water. Light regulate elongation and widening of the shoot. The short turf, cushion, mat formation and greenery in bryophytes are directly related with the intensity and quality of light. The greenish species require dim light, however pale green to brownish green or pinkish brown plants grow in exposed areas and survive to high intensity of light (*Scapania* sp., *Radula* sp., *Frullania* sp., *Herbertus* sp.). Similarly, the external capillary water plays significant role for those mosses which have sufficient amount of soil water with them. In some cases the aerial part is predominant because of their crowded shoots, branching and tall turfs. They show high values for capillary water conduction. In other mat forming and pendulous bryophytes the growing tip require water either from air moisture or dripping water. The mosses close to fall are the example for such population development. Certain remarkable and imperative community structure of bryophytes in different ecosystem is elaborated below.

Tropical Rain Forest Bryophytes

The tropical rain forest is a range of land on earth that lies within the latitude 28 degree north or south of the equator and is amongst specific type of ecosystem. It covers the area between tropic of cancer and tropic of capricon. Tropical rain forest ecosystem experiences high average temperature (20°-27°C) and a significant amount of rain fall (600-800 cm) that favours luxuriant growth and development of floristic wealth. Climate show relatively low seasonal fluctuations thus rains are not interrupted by other seasons longer than 2-4 months. The forests are characterized by frequent rains, multifaceted structure of floristic cover, complex canopy with emergent tall trees, dominating smaller trees, shrubs, ferns, bryophytes which are evergreen throughout the seasons. This ecosystem provides a large variety of habitat for bryophytes growth, because of their different microclimatic conditions and the substratum of their growth (Richards, 1954). The diverse microclimatic conditions and suitability of the substrata are determined by different amount of light, temperature, water, micro and macronutrients in the soil and the stem bark or part of phorophytes where bryophytes grow. Microclimatic conditions are also influenced by the relative humidity and by the physical and chemical properties of the substrata. The ground layer (soil, humus, litter, dead woody plants), understory layer (gaps in the branches of shrubs, tree trunk at chest height), canopy layer (circular circumference of the leaves of tree), emergent layer (certain emergent trees from the canopy layer) exhibit different factors (water, nutrients, light etc) and offers habitat for bryophytes growth. Few of the bryophytes *Cyathodium* sp., *Thudium* sp., *Mnium* sp., (Fig. 3-D), *Fissidens* sp., (ground layer); *Meteoriopsis* sp. (Fig. 3-E), *Chandonanthus* sp., *Herbertus* sp. (understory layer); *Aphanolejeunea* sp., *Lejeunea* sp., *Cololejeunea* sp. (canopy layer); *Cololejeunea* sp., *Leptolejeunea* sp., *Cheilolejeunea* sp. (emergent layer) are representatives of the ecosystem. But the intensity and penetration of light shows a very uneven distribution pattern of bryophyte diversity in vertical as well as horizontal zone of the tropical rain forest.

Desert Bryophytes

A desert is a range of land on earth that is very dry for the reason of low rainfall forming a specific ecosystem. This ecosystem is distinguishable with little coverage of plants which will be subjected to severe drought during a time of great heat. The range of land dries up unless they are supplied water from outside areas. It receives less than 25 cm of rainfall annually thus the bryophytes growing in the region have special adaptations to survive with this little water. Due to scarcity of water across the region the bryophytes grow in discontinuous and discrete patches. During rainy period bryophytes attempt to increase and colonize but by the rise of temperature and extreme desiccation, communities of bryophytes are rolled up, shrivelled and sunk in to soil surface and finally disappear. They can reappear only with a shower of rain or heavy dew overnight. So it is sporadic rain or heavy dew that decides fate of bryophyte vegetation in desert region (Smith, 1982). Even then there are many smaller areas (rocks and rock crevices, sand dunes, seepage areas and ponds, soil crusts, saline habitat, epiphytes) in desert regions that offers habitat for bryophytes growth. In rocks and rock crevices bryophytes flourish best because of moisture, shade and appropriate temperature are established. The *Targionia* sp., *Marchantia* sp., *Mannia* sp., *Exormotheca* sp., is common example in this habitat. Similarly, in sand dunes the species of bryophytes (*Tortula, Barbula, Ceratodon*), in seepage (*Riccia, Sphaerocarpos*), in soil crusts (*Cephaloziella, Cephalozia*), saline habitat (*Riella, Funaria*), epiphyte (*Tortula, Triodia*) are common.

Bryophytes Vegetation in Polar Region

The polar region of the globe is areas that surround the poles. The north and south poles of the globe being centres are dominated by the ice caps, resting respectively on the Arctic Ocean and the continent of Antarctica. In the North Pole region areas expands from high arctic to lower arctic, however the Antarctica comprises Sub-Antarctica to Antarctica regions. The polar region are characterised by snow cover, variable temperature ranges (-43° C to 10° C), variable intensity of light, frost, precipitation (7-258 cm rainfall annual). With these environmental factors and availability of water, bryophytes are very significant in the polar ecosystem in term of aerial cover, species diversity and biomass as well as energy production. The polar region particularly Arctic region offers opportunity for the growth and community building of bryophytes in different ranges i.e. wetlands, mesic regions and polar deserts. In wetland the species *viz.* (*Drepanocladus* sp., *Cinclidium articum, Seligeria polaris, Riccardia pinguis, Sphagnum* sp.); in mesic (*Hypnum revolutum, Abietinella abietina, Arnellia fennica*); in polar desert (*Hypnum bambergeri, Distichum capillaceum, Ditrichum flexicaule*) are fragmentally recorded. The vegetation cover of bryophytes in polar regions are influenced by the abiotic factors particularly water precipitation, light, temperature and nutrients.

Bryophytes Vegetation in Alpine Region

The term 'Alpine' is applied to 'Alps' which in

European languages stand for height. In real sense the alpine is one of the great mountain range systems of Europe extending across eight alpine countries. These mountains were formed over hundreds of millions of years as the African and Eurasian tPectonic plates collided. Alpine term is often used in a general sense for elevated areas inside or outside of Europe (Smith, 1982). Vegetation belt above timber line is commonly called alpine vegetation. In these regions the climate is always humid and the precipitation occurs when snow is for prolonged period. Vegetation period above the timber line remains for 3-4 months and is gradually reduced towards snow line. Snow cover is influenced by wind and under the snow cover areas temperature rarely fall below freezing point. The assimilation under snow cover occurs which depends on the intensity of light penetration, but surprisingly it protects from the desiccation because there is no evaporation under the snow cover (Geissler, 1982). Main habitat for alpine bryophytes is wet sites particularly the running water, streams, spring, rock faces and boulders. On the basis of the preferential substratum for the growth, the alpine bryophytes may be categorized in to hydrophyllous, xeric and mesic communities. In hydrophyllous communities, the species *Drepanocladus aduncus, Riccia breidleri* form population in the habitat of standing water; *Dicranum undulatum, Cephalozia connivens, Sphagnum fuscum* in mire; *Brachythecium glaciale, Distichum inclinatum, Polytrichum juniperum in snow bed; Philonotis seriata, Aneura pinguis, Bryum schleicheri, Scapania irrigua* in spring; *Fontinalis antipyretica, Rhynchostegium riparioides, Hygrohypnum dilatatum* in running water. In xeric habitat majority of the species (*Grimmia donniana, Polytrichum peliferum*) grow on rocks adopting the tendency of saxicolous. In terrestrial habitat the *Campylopus schimperi, Paraleucobryum albicans, Anoectangium aestivum, Lejeunea* sp. (Fig. 3-F) usually grow on the wet soil. The corpophyllous bryophytes (*Tayloria rudolphiana* and *Splachnum* sp.) are not unusual in the alpine communities, because of the excrete of the animals and birds retains moisture and nutrients for the bryophytes growth and development.

Conclusion

Unlike other plant groups, bryophytes have primitive tissues for conducting food and water (leptoid and hydroid), but they lack a protective outer surface to maintain water balance. These conductive strands are absent in liverworts (except *Metzgeriales*) and hornworts (excluding columella), which however predominantly occur in mosses. They are very conspicuous and distinct because they lack root system and obtain their water throughout the plants surface with their environment. They grow on moist, shady and rainy places because they require water for movement of their sexual gamete (antherozoids) during fertilization. The gametophytes usually grow on terrestrial habitat but they require water for their growth and development. Because they grow on both (terrestrial as well as aquatic) habitat, thus are called amphibian plants.

They are quite interesting living organism for very specific physiological behaviour. In contrast to ultimate dependency on water in one way, it has also been noticed that the bryophytes have capacity to withstand in the extreme cold, snow covered and desiccation condition. Bryophytes once dehydrated completely appear as dead but they regain vitality and normal physiological behaviour when are moistened and rehydrated.

Since the bryophytes are very conspicuous in their architecture and cellular compo-sition therefore the success of their life span is regulated by many macro and micro factors. But, the major factors for their growth, development of organ (rhizoids, thallus, gemmae, leaf, stem, male and female sex organs, perianth, capsule, elaters, spores), invasion of individual species, establishment of population, species succession, species community, succession and biodiversity occupancy in any region is promoted and regulated by the water in one or various ways. Thus water play significant role in the success story of bryophytes population, community structure and biodiversity gradients in variable habitats including aquatic, terrestrial, epiphytic, desert, cold, alpine, saline, polar or tropical rain forests of the world.

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