Section – B

STUDIES ON MORPHOLOGY, ANATOMY, PALYNOLOGY AND ECOLOGY OF BRYOPHYTES IN RELATION TO POLLUTION.
Chapter – 4

Introduction

(Review of Literature on Bryophytes, with special reference to its habitat quality).
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The word bryophyte was first introduced by Braun (1864). The Bryophyta includes the simplest and most primitive members of Embryophyta. They are commonly known as Lilliputians of land plants. The bryophytes grow frequently in humid and shady places. As water is indispensable for the act of fertilization, they are treated to be the amphibians of Plant Kingdom. They grow in variety of habitat. They are predominantly terrestrial (growing on soil) but mostly prefer moist places of soil near river or stream banks. Some of them are aquatic (floating on water surface or occasionally submerged) and or epiphytic (growing on bark of trees) or epiphyllous (growing on leaf surface).

The bryophytes occupy the position in between algae on one hand and the Pteridophytes on the other. Eichler (1883) divided bryophytes into two groups – Hepaticae and Musci. Later on, Engler (1892) divided the class Hepaticae into three orders – Marchatiales, Jungermanniales and Anthocerotales. A large number of botanists, like Fritsch, 1929; Buch et. al., 1938; Wettstein, 1933-35; Bower, 1935; Evans, 1939 and Engler et. al., 1954 still follows the same traditional system of classification of bryophyta, Campbell, 1918&1940; Smith, 1955; Takhtajan, 1943&1953 and Schuster, 1953&1958 divided the bryophyta into three classes – Hepaticae, Anthocerotae and Musci. In 1951, Rothmaler
changed the class names, he recognized Hepaticae as Hepaticopsida; Anthocerotae as Anthoceropsida and Musci as Bryopsida. The latest classification of bryophytes, on the basis of their taxonomy was presented by Crum (2001) in his book “Proposal for a Recorded Taxonomy, of Bryophytes”. He recognized five divisions viz; Bryophyta (with the classes Bryopsida and Andreaeopsida), Takakiophyta (accommodating the two species of Takakia), Sphagnophyta (a new division with the orders SphagnaJes and Ambuchananiales), Hepatophyta (with the classes Marchantiopsida and Jungermanniopsida) and Anthocerotophyta.

Although bryophytes, which have been serving mankind since very ancient time, are very common even then, common people do not know too much about this group of Plant Kingdom. But in recent years various applied aspects of bryophytes have come to light, eg. Food source (Han-Po-Ting, 1950; Sugawa, 1960; Bland, 1971; Richardson, 1981; Pant and Tewari, 1989), medicinal uses (Flowers, 1957; Pant et. al. 1986; Kumar et. al., 2002), seed beds for higher plants (Nichols, 1918a & b; Gates, 1930; Cox and Westing, 1963), decoration (Britton, 1902; Boffey, 1975; Miller, 1981), fuel (Thieret, 1956; Tripp, 1988; Takaki et. al., 1982), pesticides (Matsuo et. al., 1979a & b; Yepsen, 1984), horticulture (Perin, 1962; Ishikawa, 1974; Sjors, 1980) as rock and mineral builders (Ando and Matsuo, 1984; Pant, 1981; Pant and Tewari, 1983 & 1988; Nath et. al., 2001), bioindicators (Le Blance and Desloover, 1970, Welsh and Denny, 1980; Bargagli et. al., 1995; Saxena and Saxena, 2000; Sexena et. al., 2002).
Bryophytes are simple, gametophytic, non-vascular and short-lived plants. They are very sensitive to polluted water, which is absorbed by rhizoids or by whole body surface. The polluted water effects the external morphology like size, shape and colour, number of rhizoids per unit area, anatomy, ecology, palynology, physiology.

During a survey of bryophytes Pant and Tewari (1984) reported a number of bryophytes, from streams of Nainital region, who observed that the fast flowing streams were colonized by Ceratoneuron commutatum (Hedw.) Roth. and Eurhychium riparioides (Hedw.) Richs., while the slow flowing streams supported a rich assemblage of liverworts and mosses like Dumortiera hirsula (Sw.) Nees, Marchantia nepalensis Lehm. et Lindb., Pellia endiviaefolia (Dicks.), Chiloscyphus polyanthus (L.) Cord., Anomohryum filiforme (Dicks.), Barbula gracilenta Mitt., Eurhynchium riperioides (Hedw.) Richs., Fissidens grandiforms Brid., Fissidens nobilis Griff., Hydrogonium consanguineum (Thw. et Mitt.) Help. and Philonotis fontana (Hedw.) Brid.

Pande et al., 1995, who initiated a survey of bryophytes along the river Ganga between Shuklaganj (Unnao) and Kalakankar (Pratapgarh), reported two liverworts – Riccia frostii Aust. and Riccia gangetica Ahmad, and seven mosses viz; Trematodon capillifolium (C. Muell. Ex. Roth.), Physcomitrium indicum (Dix.) Gangulee, Physcomitrium japonicum (Hedw.) Mitt., Hydrogonium consanguineum (Thw. et Mitt.) Help., Fissidens curvato-involutus Lix., Fissidens involutus Mitt. and Funaria hygrometica Hedw.
Jagdish Lal (2001), who initiated a survey of bryophytes at Allahabad and its adjoining areas, found that bryoflora were not rich but the diversity was very significant, which is evident from the fact that all three classes viz; Bryopsida, Hepaticopsida and Anthocerotopsida are distributed there. It consists of 18 mosses, 9 liverworts and only one hornwort. Their family and number of genera and species given in brackets are as follows: Archidiaceae (one genus, one species); Funariaceae (one genus, three species); Sphachnaceae (two genus, two species); Eupodiaceae (one genus, one species); Bryaceae (one genus, one species); Pottiaceae (three genera, six species); Trematodontaceae (one genus, one species); Fissidentaceae (one genus, three species); Cyathodiaceae (one genus, one species); Aytoniaceae (two genera, two species); Ricciaceae (one genus, six species) and Notothylaceae (one genus, one species).

A lot of work has been done on taxonomy, morphology, anatomy, palynology and physiology in India by Udar, 1976; Gupta and Udar, 1986; Bharadwaj, 1971&1972; Sharma et. al., 1981; Sood, 1974; Kaushal and Kaushal, 1984; Pant, 1981; Pant and Singh, 1986.

The effect of moisture content on the morphology of a bryophyte (Riccia fosstii) was observed by Pande (1924). He concluded that the thalli become narrower in the presence of excess moisture content (under experimental conditions). A study on terrestrial moss community at Varanasi was conducted by Dutta Munshi (1974). She observed that when the moisture contents of soil comes down to one forth of the field capacity of the soil (27%), mosses starts drying up
and when the same was increased to 50% of field capacity of the soil, the plants were growing luxuriantly. She also concluded that the two mosses (*Hydrogonium consanguineum* (Thw. et Mitt.) Help. and *Hypophylla sphathulata* (Harv.) Jaeg.) may be used as indicator species for moisture contents of soil. The ecological studies of Family Ricciaceae were conducted by Patidar (1982). He noted that *Riccia gangetica* Ahmad. and *Riccia fluitans* L. emend Lorb. showed best growth at 50% and 70% moisture contents respectively. Later on, patidar (1988a) compared thallus measurement of *Asterella angusta* (Steph.) Kachroo, with soil moisture level, relative humidity and temperature measurement at two sites and concluded that the moisture content is the most important variable associated with the thallus size. Glime (1987a, b, c) indicated that the aquatic bryophytes are very sensitive for high temperature and their presence can, therefore, indicates that it dose not remain hot for a long period of time.

Generally, the bryophytes are most sensitive during autumn and early winter with their tolerance increasing through spring to maximum in early summer (Dilks and Proctor, 1976a; Richardson and Neiboer, 1980). The surface stabilizing properties in some mosses (*Barbula fallax* Hedw., *Bryum apiculatum* Doz. & Molk. and *Ceratodon purpureus* (Hedw.) Bird, was observed by Gimigham (1948), Birse *et. al.*, (1957) and Johnson (1962). Taoda (1977) suggested that the few bryophytes *Atrichum angustatum* (Bird), *B.S.G., Eurhynchium savatieri* Besch., *Brachymenium exile* (Dox. & Molk.), *Ceratodon purpureus* (Hedw.) Bird, *Marchantia polymorpha* L., *Tortula*
*rhzophylla* (Sak.) Iwats. et Saito are good indicators of soil pH (4.5 – 6.0, 4.7 – 5.4, 4.05 – 5.4, 4.1 – 5.4, 5.5 – 6.9, 6.0 – 7.5, 6.1 – 7.4) because they receive most of their water and nutrients from air. *Polytrichum* sp. are a reliable indicator of acid condition (Crum, 1973).

The spore morphology is characteristic and very significant feature in taxonomical studies. The earliest study, in this connection was made by Udar (1957). Udar and Gupta (1979) in a preliminary palynological investigation of three species of genus *Riccia* – *Riccia cruciata* Kash., *Riccia crystalline* Linn. and *Riccia frostii* Aust. showed an interesting range of tetrad mark including monolette, bilete, trilette and ‘H’- shaped types. Inoue (1960) provided general information on spores of the Marchantiales. Miyoshi (1966) studied the spores of Japanese Hepaticae. Whereas Mehra and Sood (1969) published a paper on spore morphology of some Hepaticae and Anthocerotae from western Himalayas. Boros and Jarai – Konlodi (1975) presented spore morphology of some European members of Hepatics using herbarium specimens. They investigated them in acetyolysed preparations (Under LM, some under SEM) and provided details of shape, size, range, ornamentation and thickness of exine. Ono (1966, 1966a&b) published paper on spore morphology of *Jungermanniales*, he presented the pattern of sculpturing in few genera. Sharma *et. al.*, (1981), published an article on palynology of some liverworts from Garhwal Himalayas. LM studies on the spores of *Riccia curtisi* (Aust.) JAMES have been studied by Tewari and Pant (1983), collected from a side of lake in Mohanlalganj (Lucknow). Kumar *et. al.*,
(highly polluted) site, they also noted that the male plants appeared to be more susceptible to polluted water than those of female plants.

The effect of mineral nutrients, chelates and organic nitrogenous source on growth and sexuality in *Riccia crystalline* L. was studied by Sood (1974). She concluded that all nutrients were toxic when presented in high concentration and were ineffective when presented in extremely small amount. Shukla (1971), who found that the fresh weight and dry weight production of *Marchantia polymorpha* L. and *Plagiochasma appendiculatum* L. et L. were inhibited above 0.05% nutrient concentration. The best growth was observed at 0.02% concentration of Potassium dihydrogen ortho phosphate, Calcium nitrate, Calcium chloride, Magnesium sulphate and Potassium nitrate in culture experiments (Patidar et al., 1988). The mosses easily accumulate Potassium, Calcium and Magnesium from rainfall (Thimmer, 1970). Rieiley et al., 1979, reported that minerals are mainly supplied by rain and by the leaching of the canopy. Thus bryophytes play an important role in retaining the minerals that might otherwise be quickly leached from the soil.

Few bryophytes have been found to be closely associated with particular mineral deposit ion, but Pant (1981) considered certain metal tolerant bryophytes to be potential tool for geobotanical prospecting, whereas Shacklette (1984) suggested that the use of aquatic bryophytes for geobotanical prospecting. The high nitrogen fixation rate (0.8 – 3.8 gm⁻² y⁻¹) reported by Granhall and Lindberg (1978) in wet *Sphagnum* communities in a mixed pine and spruce forest
in central Sweden. The bryophytes (liverworts and mosses) provide suitable substrates for the biological fixation of Nitrogen in association with Cyanobacteria (Blue-green algae) (Saxena, 1981 and Toppo et. al., 2002). The concentration of some mineral nutrients (Nitrogen, Potassium, Phosphorus and Calcium) and biomass contents in few epiphytic bryophytes was studied by Joshi et. al., (2002). The nutrient concentration (N, P, K and Ca) in epiphytic bryophytes were determined seasonally and concluded that the Calcium concentration was invariably higher than other nutrients.

Studies on chemical constituents (Nitrogen, Protein, Carbohydrates, Calcium and Magnesium) in ten species of mosses which were collected from Mt. Abu have been carried out by Deora and Chaudhary (1995). They observed that the percentage of Nitrogen, Protein, Calcium and Magnesium were comparatively higher in vegetative stage than sporophytic stage. But Carbohydrate contents are comparatively higher in sporophytic stage of selected mosses than vegetative ones.

The chlorophyll content is an ecological index as well as growth parameter (Bilage and Mall, 1975). Studies on chlorophyll concentration (chlorophyll a, chlorophyll b, total chlorophyll a+b and ratio a/b) have been the subject of considerable interest of bryologists. Chlorophyll concentration in two moss communities like Hydrogonium sp. and Physcomitrium sp. was observed by Dutta Munshi (1974). She concluded that it was lower in the former species than in later species. Rao et. al., 1979, studied the total chlorophyll and chlorophyll a/b
ratio in two species of liverworts (Marchantia polymorpha L. and Marchantia palmata Nees), and in some higher plants. Sharma and Chopra (1987) studied the toxic effect of Lead (Pb), (Lead acetate and Lead nitrate) on chlorophyll concentration in Semibarbula orientalis (Wed.) Wijk & Marg. under laboratory condition. They found that, a little increase of Lead salts concentration in the medium, adversely affect the chlorophyll content. They also observed that the Lead nitrate was more toxic than Lead acetate. In the same year Pande and Singh (1987) also observed chlorophyll contents and carotenoids concentration in ten bryophytes from Nainital Kumaon Himalayas. They observed that concentration of chlorophyll in bryophytes was directly affected by low and high solar irradiance. They further observed that the total chlorophyll concentration was higher in liverworts than in mosses.

The lowest chlorophyll concentration in two bryophytes (Riccia frostii and Physcomitrium indicum), collected from River Ganga bank between Shuklaganj (Unnao) and Kalakankar (Pratapgarh) was studied by Sinha et. al., 1992, who concluded that the chlorophyll concentration is directly affected by higher concentration of Magnesium in the sediments of river water at Shuklaganj and Kalakankar. The effect of simulated acid rain on the morphology, growth and chlorophyll content of Hylocomium splendens (Hedw.) B.S.G. was studied by Bakken (1993). A reduction in segments length, branch length, a number of branches, segments dry weight and chlorophyll content was observed with increasing acidity in the spray treatments at pH < 4.0.
Bryophytes are highly suited for studies on pollution because they are the simplest of green land plants, both morphologically and anatomically. The suitability of bryophytes (liverworts and mosses) as bio-indicators is mainly due to their simple thallus or one celled thick leaf surface, lack of any protective layer, absorption and accumulation of pollutants directly from the atmosphere, absence of vascular supply for transportation of mineral within the plants, green and perennial growth in a wide variety of habitats, ability to stored for several years without much care and old samples can be chemically analysed easily. These above characters make them most susceptible for water pollution (Manning and Feder, 1980). Barkman (1969) concluded that the cryptogams were more sensitive to pollutants than vascular plants. Coupal and Lalancette (1976) suggested that *Sphagnum* sp. can be used to remove heavy metal ions like Ag, Cu, Cd, Hg, Fe, Sb and Pb. Pant (1981) identified some liverworts and mosses as indicator organisms of various heavy metals. She also reported some metal tolerant bryophytes. Concentration of heavy metals (Pb, Cu, Ni, Mn and Cr) in *Plagiochasma* sp. was reported by Saxena and Saxena (2000). Some heavy metals concentration in terrestrial moss (especially *Hylocomium splendens* (Hedw.) B.S.G. and *Pleurozium schreberi* (Bird.) Mitt. have been determined by Reimann et. al., 2001.

The concentration of selected heavy metals (Cu, Cr, Pb, Zn, Ni and Cd) in two bryophytes (*Riccia frostii* and *Physcomitrium indicum*) growing on the banks of River Ganga between Shuklaganj (Unnao) and Kalakankar (Pratapgarh)
was studied by Pande et al., (2001), who suggested that the *Riccia frostii* and *Physcomitrium indicum* may be used as a bio-indicator and accumulator of heavy metals. The Lead (Pb) concentration in *Hypnum* sp. at different habitats of Kumaon hill was studied by Saxena et al., (2002). Higher Lead concentration was observed in the harvested moss, transplanted at urban sites of Almora and its concentration decreased at peripheral rural sites.

**Present Study**

The investigation of River Sai at Rae-Bareli city between Lohanipur and Behta Picnic Spot in respect to its water quality have been conducted by some previous hosts like Sinha et al., 1985; Kumar and Kant, 1987; Vajpayee and Sinha, 1988; Sinha et al. 1994 and Srivastava, 1995. Studies on River Sai with special reference to its fauna and flora have been conducted by Srivastava (1995) and Singh (1996).

A perusal of above-mentioned studies would reveal that the River Sai at Rae-Bareli city between Lohanipur and Behta Picnic Spot has not been investigated in respect to its bryoflora, which are growing on its beds (Polluted habitat) and upland region (Non-polluted habitat). The pollutants ultimately settle down and disturb the normal concentration of river beds and its catchments area. These naturally affect the bryoflora harboring in these habitats. Hence, the present studies on bryophytes with special reference to water pollution and our observations have been presented in the following chapters.