Role of Bryophytes in Soil Management and Rock Binding

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A critical field observation and detailed literature survey have shown the significant role of bryophytes in soil management. Their role in rock building, soil binding, land conservation, mineral indication, slope formation, erosion prevention has been discussed here. Besides, their remarkable capacity to grow after sand burial has also been taken into the account.

Key-words–Bryophytes, Soil management, Rock binding.

INTRODUCTION

IN recent years various applied aspects of bryophytes has come to light, e.g. horticultural uses, use as material for decoration, medicinal uses, as flood and erosion controllers, as seed beds for higher plants, as rock and mineral builders, use as bioindicators (Ando & Matsuo 1984). Besides, a number of biologically active substances have also been detected and chemically analysed from various liverworts and mosses (Asakawa, 1981). However, not much is known about the role of bryophytes in soil management. Though some scattered informations have been provided earlier by various workers from time to time (Grout 1912; Emig 1918; Brinkman 1929; Leach 1931; Birse *et al.* 1957; Marsh & Koerner 1972; Brooks 1972). In the present account role of bryophytes in soil management and rock binding in various ways has been reviewed and discussed.

SITE SPECIFICITY

It has been noticed that some liverworts are very specific for their sites. The specificity of certain taxa for a particular microclimate can be utilised as markers. Various species have been visualised as site indicators in relation to forest bearing capacity of sites (Brinkman 1929). *Lophozia barbata* (Schimd.) Dum. and *L. lycopodioides* (Wallr.) Steph. both are indicators of rather dry situation while *L. incisa* (Schrader) Dum. and *L. heterocolpa* (Thed.) Howe. frequently grow in moist sites. *L. incisa* (Schrader) Dum. was found as indicator of more humid situation than *L. ventricosa* (Dicks.) Dum. and *L. heterocolpa* (Thed.) Howe.

SOIL BINDING

In exposed situation at hill tops (ca 2000 ft.) where the rocks are usually soft and liable to weather down into small fragments of about 1 or 2 cms in diameter, *Polytrichum piliferum* Hedw. is found as an important agent in stabilisation of the substratum and initiation of recolonization (Leach 1931). Presence of *Polytrichum juniperinum* Hedw., *P. piliferum* Hedw. and *Ceratodon purpureus* (Hedw). Brid. as pioneers on various types of soil is well known. On investigations (Leach, 1931) it has been revealed that early appearance of *Polytrichum* Hedw. is often due to vegetative growth of small fragments of moss that established between the stones. These fragments get anchored to the substratum and protrude up new leafy shoots. A far more extensive underground system of stems and rhizoids usually grow than its appearance above the ground level. The binding action of rhizoids upon the fine soil between the stones and upon the stones themselves becomes evident if we try to free the moss from the soil by washing. These species are able to form the rhizome like shoot even in the absence of light mainly due to their specific photosynthetic activity which provide food reserves to them that enables them to grow.

One can easily see in the bryologically rich fields, large patches of thalloid liverworts e.g. *Marchantia* L. (Fig. 4), *Plagiochasma* Lehm. *et* Lindenb. (Fig.1), *Conocephalum* Web., *Targionia* (Mich.) L., *Asterella* Beauv. etc. forming dense mat over the soil covered rocks in a fairly large area, due to their compact rhizoidal system binding the soil particles together thus preventing the soil erosion. Besides, some mosses i.e. *Polytrichum* Hedw., *Physcomitrium* (Brid.) Fuernr. etc. luxuriantly grow as rock cover and protect them from weathering.

MINERAL INDICATION

The presence of *Mielichhoferia elongata* (Spr.) Schimp. has been reported in substrates having 320-770 ppm copper concentrations which is 100 times higher than the trace concentration in ordinary soil. It clearly suggests its resistance to higher copper con-

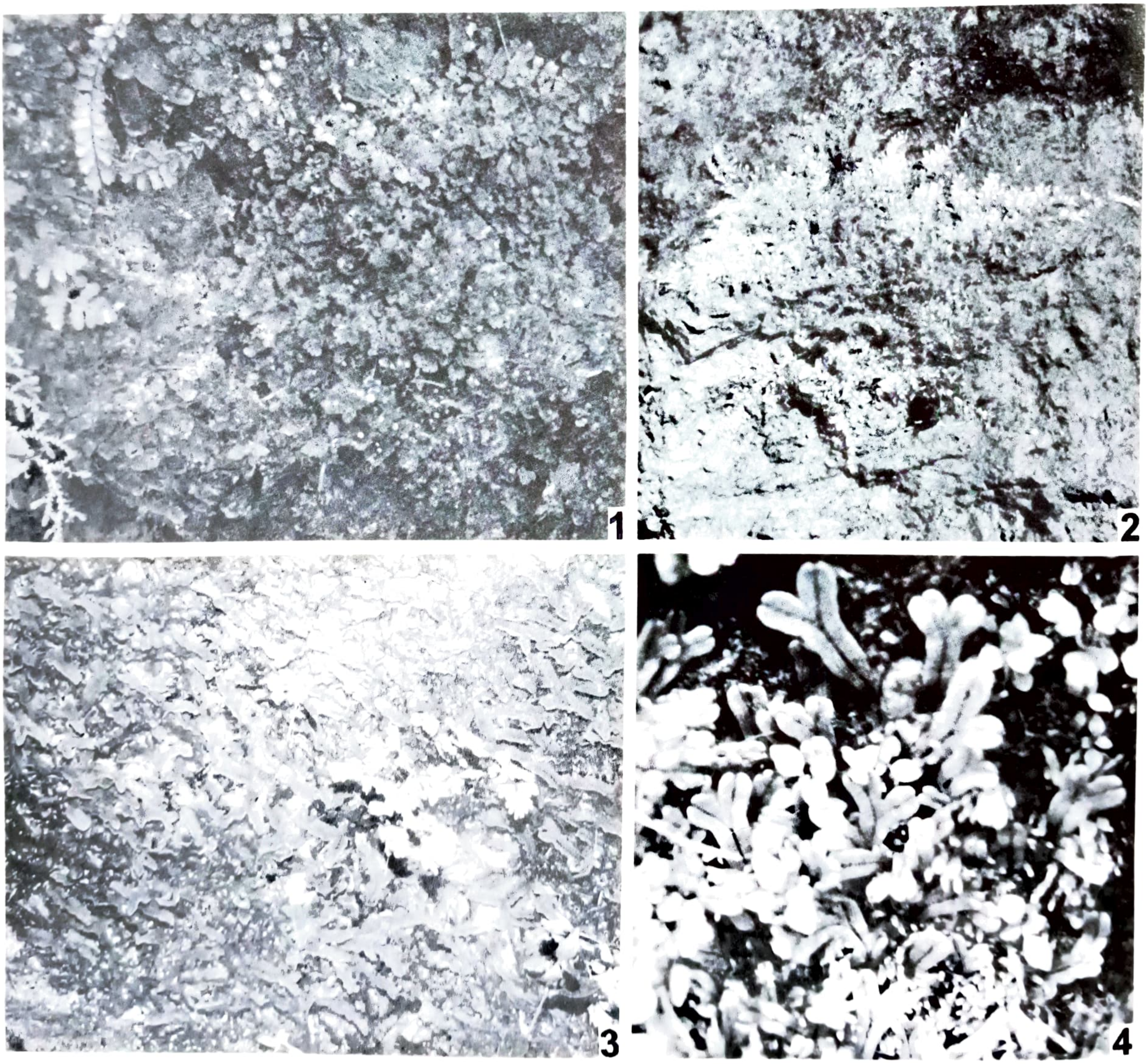

Fig 1. Dense mat of *Plagiochasma intermedium* growing over soil covered rocks. **Fig. 2.** Growth of *Plagiothecium* sp. over rock. **Fig. 3.** A dense colony of *Dumortiera hirsuta* growing under dripping water at Tamia Valley (M.P.). **Fig. 4.** *Marchantia subintegra* forming a mat over soil covered rocks.

centration. *Merceya ligulata* (Spruc.) Schimp. and *Mielichhoferia elongata* (Spr.) Schimp. are usually known as 'copper moss'. *Merceya mielichhoferia* (Funck ex Hook.) Loesk. grow preferentially over substrates with higher copper concentrations (Brooks 1972). Their specificity to copper rich area can be utilised in mineral exploration. Localities are generally mentioned on the labels of Herbarium specimen packets which can be utilised for mineral indications. During the studies on Bryophytes of Kumaon region (Pant & Tewari 1995) growing at mineral rich substrates it has been observed that *Grimmia pulvinata* (Hedw.) Sm. form the cover over mica-schists, whereas hard granite rocks and boulders were usually covered with another species of *Grimmia*. The flaky masses of graphite-schist were covered with *Bryum cellulare* Hook. The iron rich substrates are usually found covered with *Tortella* sp., *Oxystegns* sp. and *Zygodon viridissimus* (Dicks) R. Br., however, species of *Campylopus* made conspicuous presence over these iron rich substrates. Over the rocks covered with Gypsum rich soil, *Asterella* sp., *Anoectangium stracheyanum* Mitt., *Barbula horricomis* Gangulee, *Bryum capillare* Hedw. and *Brachythecium buchanani* (Hook.) Jaeg. etc. form dense mats. Utilising these remarkable characterstics of bryophytes one can easily find out the exact chemical nature of substrate on which they grow. Any change in bryofloristic pattern provides an initial sign or indication that there is a soil and underlying rock change. This substrate specific growth of a particular taxon can be successfully exploited for a better soil management and its applications related to Agroforestry development.

SAND BURIAL

A very significant experiment has been performed (Birse *et al*. 1957) to see the effects of burial by sand on dune mosses. Eighteen species of mosses have been selected for experimental investigation of the sand burial. As a result of different lines of experiment it was revealed that *Ceratodon purpureus* (Hedw.) Brid., *Bryum pendulum* Brid. and *Brachythecium albicans* (Hedw.) B.S.G. have capacity to emerge out from beneath the 4 cms after the sand burial. However, *Polytrichum piliferum* Hedw., *P. juniperinum* Hedw. and *Pohlia annotina* (Hedw.) Lac. marked the power of recolonization even after burial up to 7cms beneath the sand. *P. annotina* (Hedw.) Lac., *Ceratodon purpureus* (Hedw). Brid. and *Dicranum scoparium* Hedw. also restablised themseleves by means of vertically extending rhizoids producing protonemata at the surface. The maximum depth from which the various species can emerge, the depths from which effective recolonization of the surface is achieved within a fairly short time, the ability to produce rhizoids in the overlying sand and the growth form of the shoots on emergence are regarded as the most significant aspects of reaction to burial, in relation to the role of species in their natural habitats have been noticed.

ROCK BINDING (TRAVERTINE AND TUFA FORMATION)

One of the most important role in soil management is the quality of some mosses to build up the rocks. The critical observation (Emig, 1918) of the process of rock building has revealed that the dense tufts of *Didymon* Hedw. are more commonly distriubuted along moist ledges extending across the shallow streams. These plants had a greater share in building the travertine as compared to the plants of *Philonotis* Brid. The dense moss tufts formed from one to four inches above the surface of water at the margin of waterfalls are always saturated like a sponge. As the water evaporates from the leaves and stems most of free CO_2 escapes in the air and only a comparatively small amount of free CO_2 or CO_2 derived from the bicarbonates in solution is used by the mosses during the process of photosynthesis. The changed equilibrium by the loss of CO_2 from mineral water is perhaps followed by a separation of $CaCo_3$ in such a manner as to form a white crystalline covering over the outer surfaces of the plants. Thus, takes place transition from the moss plant to incrustation and eventually to a compact limestone, which is a very slow development. The gradual accumulation of calcite gives rise to a hard but cavernous limestones. Then the water mosses growing in shallow current help in cementing the boulders into a conglomerate dam. It is clearly evident that mosses act indirectly in the precipitation of $CaCO_3$ mainly by providing a larger absorptive and adsorptive surface for the evaporation of the calcareous water. Similarly, observations (Pant 1987) have also been made at Sahastradhara, Dehradun, (U.P.) that bryophytes are the most active biological agents involved in building up the biogenic rock-tufa. It has been observed that *Bryum cellulare* Hook., *Hydrogonium gracilentum* (Mitt.) Chen. and *Vesicularia montagnei* (Bel.) Broth. form heaps and get solidified in the form of incrustation and solid accretions. *Chiloscyphus polyanthus* (L.) Corda, *Pellia endevaefolia* (Dicks.) Dum., *Philonotis calcarea* (B.S.G.) Schimp. and *Hydrogonium gracilentum* (Mitt.) Chen. have been observed in various stages of lime incrustations i.e. from green cushions to partly incrustated ones (Pant 1987). In addition to this an assessment of bryophytic vegetation of Nainital and environs, dealing with substrate preferences of genera and species have also been provided (Pant 1987; Pant & Tewari 1983, 1988).

Bryophytes are most active biological agents involved in building up the biogenic rock-tufa. Their habit of growing in dense cushions, cliffs, rock edges and sides of stream as far up the dash of water can reach, is best adapted to take up large quantity of water and to retain it like a wet sponge. A constant supply of right kind of moist surfaces is thus available for the evaporation of calcareous water resulting in the (a) direct precipitation of calcuim salts, (b) in the removal of free CO_2 and decomposition of bicarbonate ions. $CaCO_3$ gets deposited on the outer surface of the plants as a white crystalline covering. During the studies (Pant 1987) carried out at Sahastradhara, Dehradun, U.P. 3 species of liverworts *Asterella maculata* Steph., *Chiloscyphus polyanthus* (L.) Corda, *Pellia endaevifolia* (Dicks.) Dum. and 6 species of mosses e.g. *Bryum cellulare* Hook., *Hydrogonium gracilentum* (Mitt.) Chen., *Fissidens taxofolius* Hedw., *Hymenostylium* (Hook.) Jaeg. etc. were observed flourishing well in a highly calcareous stream water initially passing for some distance.

Bryum cellulare Hook., *Hydrogonium gracilentum* (Mitt.) Chen. and *Vesicularia montagnei* (Bel.) Broth. form heaps of these solidified mossees which can be easily seen in all stages of incrustation, they also form solid accretions. *Chiloscyphus polyanthus* (L.) Corda, *Pellia endaevifolia* (Disks.) Dum., *Hydrogonium gracilentum* (Mitt.) Chen. and *Philonotis calcarea* (B.S.G.) Schimp. are seen in various stages of lime incrustations. These range from green cushions to partly incrustated ones.

LAND CONSERVATION AND SLOPE FORMATION

It has been noticed (Grout 1931) that mosses act as a factor in land conservation. On examination the top of elevation found covered with a fine net work of moss protonema, which has probably protected the soil beneath from rain similarly as chip protects the snow from the spring sun. Species of *Hygrohypnum* Lindb., *Brachythecium* B.S.G. (Fig.2) and *Amblystegium* (Hedw.) form a covering over stones and soil along the bed and banks of the streams by densely packing the sand and soil. This type of formations (Fig.7) protects the bed of stream from being eroded by the running water during the spring. The abundant rhizoid production and massive tomentum in *Hydrogonium* seems to make it most efficient consolidator and binder of loose calcareous rocks (Pant & Tewari, 1995) as observed at Kilbury (Dist. Nainital) also where *Hydrogonium gracilentum* (Mittt.) Chen. and *Hymenostylium recurvirostrum* (Hedw.) Dix. form a dense mat cover over the rocks (Fig.6).

Some mosses play a great role in slope formation. An investigation (Marsh & Koerner 1972) revealed that moss slopes represent an equilibrium condition between plant and coastal geomorphic processes. Many moss slopes are likely in equilibrium with various magnitude wave and wind events and therefore never actually develop beyond a moss cover with scattered woody plants before being eroded away. Moss has been noticed as dominant vegetative unit on these slopes in part because of its morphological response to the stress conditions of the crest slope environment. Moss clumps readily tolerate sand burial. It has been found (Leach 1931) that buried *P. piliferum* Hedw. produces long underground stems which are very tough. It can appear from burial depths exceeding 6 cms and it can regenerate 50% cover from burial up to 3.5 cms. This moss not only tolerates burial but it is also capable of surrounding the sand deposits. The influence of moss on transportation of sand by run off is on one hand decrease the infiltration capacity of the surface by more than one-third thereby increasing run off discharge from the slope while on the other hand it increase the surface roughness thereby reducing the competence of run off to transport sand across it. The formation of moss lobe results in a diversification of slope environment. New microhabitats principally in terms of light moisture and wind are created which lead to germination potentials not otherwise present. Analysis of mapped sites revealed that over 60% of the woody stem (*Piceia glanca* Voss., *Pinus strobus* L., *Abies balsamea* Mill., *Betula papyrifera* Marsh.) were within 15 cms and 79% within 30 cms of a moss lobe crest (Marsh & Koerner 1972).

The use of mosses and liverworts in landscape gardening have been discussed (Grout 1931) and an excellent example has been put by the use of mosses to beautify grounds in the cutting estate at great river, Long Island, New York, where beautiful shaded paths and roads are carpeted with mosses partly a natural growth and partly planted. The fine green velvet was consisting chiefly *Cephalozia bicuspidata* (L.) Dum. interspersed with *Calypogeia tenuis* (Austin) Evans. Along the raised sides of path and roads were luxuriant growth of *Mnium hornum* Hedw., *Polytrichum commune* Hedw. etc.

It has been observed in Poland and other European countries and Japan, a number of species of *Sphagnum squarrosum* Crom. and *Polytichum commune* Hedw. etc. mosses together with some herbaceous taxa and grasses have given rise to a sort of land mass on big lakes where large trees appeared successfully and formed dense "Reserve forests" (Fig.5).


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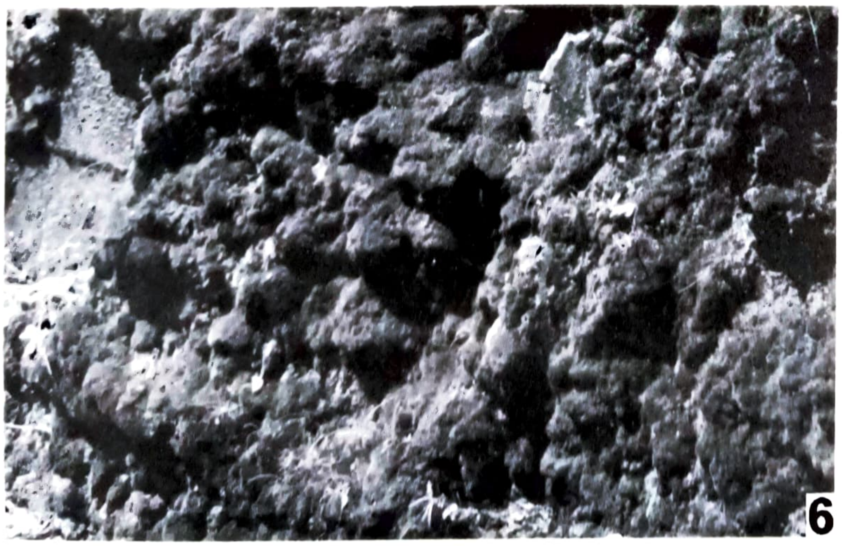
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Fig. 5. A land mass formed by *Sphagnum* L. and *Polytrichum* Hedw. spp. over a lake in Poland exhibiting growth of herbs and long trees over it. **Fig. 6.** Mixed growth of *Hydrogonium gracilentum* (Mitt.) Chen. and *Hymenostylium recurvirostrum* (Hedw.) Dix. forming cushion over calcium rich rocks at Kilbury (Nainital). **Fig. 7.** A bed of stream protected by thick cushion of moss growth at Pachmarhi (M.P.).

Therefore, it is clearly evident by the above observations that various qualities of different taxa of mosses and liverworts can be successfully utilised in management of soils and land.

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