Uses of Bryophytes

D K Saxena and Harinder

Although bryophytes are among the oldest land plants, their usefulness is relatively unknown to most people. Bryophytes are used in pharmaceutical products, in horticulture, for household purposes, and are also ecologically important. The multifarious uses and applications of the bryophyte flora are being increasingly recognized around the world. Their potential in the biomapping of atmospheric precipitation is also enormous. In this article, we briefly examine some of the uses of this ancient group of simple plants.

D K Saxena is at the Department of Botany, Barielly College, Bareilly. His current research interests are in the detoxification of metals by bryophytes, and their relevance to biomonitoring/ biomapping studies.

Harinder is at present in the Department of PG Diploma of Environmental Management, Bareilly College, Bareilly and has been involved in research on the biomonitoring potential of bryophytes.

The liverworts, hornworts and mosses are small, low-growing plants that constitute the phylum Bryophyta. Bryophytes have neither true stems, leaves nor roots, nor a vascular system. Consequently, they are confined to damp shaded areas with high humidity, and frequent rainfall. Most bryophytes are either liverworts or mosses. Liverworts grow horizontally, and are flattened or 'leafy', whereas mosses have an upright stalk with spirally arranged leaf-like structures. The pleurocarpous mosses (carpet-forming) are characterized by extensive branching and lateral sporophyte placement, compared to the terminal sporophytes in acrocarpous (erect) mosses. Pleurocarpous mosses constitute the major groups of mosses. Though tiny, bryophytes modify their micro-climate and serve to conserve moisture, check soil erosion on hilly slopes, and also serve as a seed bed for forest cover. They are now increasingly being used for purposes ranging from pollution monitoring to new sources of pharmaceutical products. Present uses of bryophytes include ecology, horticulture, construction, household uses, medicine and even food.

Keywords
Liverworts, mosses, bio-indicators, eco-friendly products, medicinal plants.

Ecological Uses

Liverworts and mosses have been found to be good indicators of environmental conditions. The occurrence of certain aquatic mosses can be used as an indicator of calcium and nutrient content in water. Some bryophytes grow only in a narrow and specific pH range and, therefore, their presence can be used as an indicator of soil pH. Bryophytes envelope the forest floor and tree trunks and aid in moisture conservation. Mosses like *Atrichum, Pogonatum, Trematodon, Pohlia, Nardia* and *Blasia* play a role as inhibitors of soil erosion due to their trample-resistant structure and their regenerative ability. Acrocarpous mosses like *Rhodobryum* and *Dicranum* prevent soil erosion of the slopes of hills because the netted and webbed protonemata cover the exposed substrata. In pastures of Nova Scotia in Canada, it has been seen that white spruce germinates most prolifically in carpets of *Polytrichum*. Many mosses, especially *Hypnum imponens*, provide excellent seeding beds for a variety of coniferous tree species. This is likely to be due to the role of bryophytes in providing moisture, appropriate temperature, and also organic matter and minerals after the death of bryophytes. Thus, bryophytes play an important role in the maintenance and replenishment of forest cover.

Some bryophytes grow only in a narrow and specific pH range and, therefore, their presence can be used as an indicator of soil pH.

Minerals supplied by rain, by leaching of the canopy, and by through-fall are trapped by bryophytes. Thus, bryophytes play an important role in retaining minerals that might otherwise be quickly leached from the soil. Mosses easily accumulate K, Ca and Mg from rainfall. Yet, at the same time, they do not compete for phosphorous in the soil. Bryophytes also play an important role in iron-ore deposition. Nitrogen is often a limiting nutrient for plant growth, especially in cold regions of the northern hemisphere. Even small contributions from biological nitrogen fixation may therefore be of importance to ecosystems. Some mosses (*Sphagnum*) and liverworts provide suitable substrates for the biological fixation of nitrogen in association with cyanobacteria. These cyanobacteria seem to behave symbiotically in these plants. Indeed, such moss symbionts are responsible for most of the nitrogen fixation in artic and sub-artic ecosystems.

Some bryophyte species have been found to be closely associated with particular mineral deposits. For example, *Merceya*, *Mielichhoferia elongata*, and *M. mielichhoferia* are known as copper mosses because they grow in copper rich soil. Such species can be used as indicator plants.

Mosses are also good indicators of acid rain, because they lack a protective epidermis and cuticle and, hence, are more susceptible than the vascular plants. In general, studies have shown that liverworts and mosses are very sensitive to air pollution. In polluted areas, standard transplantation of certain mosses has been found to be quite useful for monitoring the intensity and trend of air pollution. By making regular survey and counting abundance and frequency of species of mosses, an IAP (Index of Atmospheric Purity) can be calculated. Bryophytes have also been used to monitor airborne pollution caused by emissions from various sources. Similarly, aquatic bryophytes *Amblystegium riparium*, *Fontinalis antipyretica*, *F. squamosa*, *Eurhynchium riparioides*, and *Scapania undulata* are now used to monitor water pollution.

The suitability of liverworts and mosses as bioindicators is mainly due to their simple thalloid or one-cell thick structure, lack of cuticle or epidermis, resulting in greater absorption and accumulation of nutrients and pollutants directly from the atmosphere. Moreover, mosses can be stored for several years without noticeable deterioration and old specimens can easily be chemically analysed. Several studies have indicated that mosses accumulate heavy metals such as Pb, Fe, Zn and Ni in high concentrations. Moreover, bryophytes retain their toxic load for a long time after death because of slow release of accumulated substances. Thus, they can serve as 'environmental specimen banks' and are being used for this purpose.

The suitability of liverworts and mosses as bioindicators is mainly due to their simple thalloid or one-cell thick structure, lack of cuticle or epidermis, resulting in greater absorption and accumulation of nutrients and pollutants directly from the atmosphere.

Horticultural Uses

There is a long tradition of use of bryophytes in horticulture as soil additives, ornamental material for cultivation, and in Japanese gardens (*Figure* 1). Bryophytes are particularly popular because of their high water holding capacity and permeability to air. Peat is an important soil conditioner and is commonly used for agricultural and horticultural purposes around the world. Bryophytes have also been used for green house crops, potted ornamental plants and seedlings, and in garden soil. Gardeners use *Sphagnum* in air layering, a method of propagating plants. Fresh *Sphagnum* is also mixed with the soil or spread over the ground as a mulch. It helps to maintain moisture and prevent growth of weeds; it is permeable to air and has elasticity, making it an ideal growth medium. Use of mosses in Japan as ornamental plants for culture is very popular. Landscape tray is an alternative horticultural art of Japan in which several mosses like *Polytrichum commune, Leucobryum neilgherrense* and *Bartramia pomiformis* are used. Mosses also provide an important element for bonsai, help to stabilize the soil and are useful in retaining moisture. In addition to this, the moss looks graceful and gives a green cooling touch. In Japan, mosses have frequently been used in moss gardens because they give a quiet beauty and ancient look to gardens by clothing tree trunks, rocks and stone. A very popular moss garden is at the Buddhist temple in Kyoto, an ancient capital of Japan.

Figure 1. Moss gardens in Japan.

In Japan, mosses have frequently been used in moss gardens because they give a quiet beauty and ancient look to gardens by clothing tree trunks, rocks and stone. A very popular moss garden is at the Buddhist temple in Kyoto, an ancient capital of Japan.

Moss Industry

The physical structure of peat is highly absorbent and permeable and it has been found to absorb metals, and therefore, *Sphagnum* is used as an effective filtering and adsorption agent for the treatment of waste water and effluent of factories with acid and toxic discharge containing heavy metals (Ag, Cu, Cd, Hg, Fe, Sb and Pb), and organic substances such as oils, detergents, dyes and micro-organisms. Use of peat moss in this role appears economical for developing countries. It involves contact of waste water with peat, drying the peat by mechanical pressure, and finally burning the peat and reclaiming the metals. Peat can also be used as an effective adsorption agent for oil spills. Active

The commercial production of *Sphagnum*, which holds up to 30 times its weight in water, has been going on for over 150 years in the USA.

carbon is an important adsorptive substance in many chemical industries and it can be produced from peat (*Sphagnum*). A number of different high quality products are now commercially being produced to serve client needs in the field of pollution control and bioremediation. These products are used for the biotreatment of oil spills in marshes, mangroves, and wetlands. Conventional sorbents work slowly when applied to a spill and may subsequently release the oil, violating regulatory leachate standards. Some of the bryophyte-derived products can absorb up to 12 times their weight, and require less storage space than conventionally used materials. Transportation and handling of bryophyte-derived products are also easier, and disposal costs are lower than conventional products. Some of these bryophyte-derived products are 'hydrophobic' (do not absorb water) and 'oleophilic' (absorb oil), making them especially useful for oil spills on waterways. Some of the other fluids that can be absorbed by these bryophyte-derived products are acetone, benzene, butanol, carbon tetracholoride, chloroform, corn oils, cutting oils, diesel fuels, ethyl benzene, ethyl ether, gasoline, jet fuels, kerosene, methanol, motor oils, oil based paint, oil base ink, paraffin oils, toluene, styrene, tetrachloroethane, xylenes, and vinyl acetate.

The commercial production of *Sphagnum*, which holds up to 30 times its weight in water, has been going on for over 150 years in the USA. *Sphagnum* is an excellent material for shipment of plants and fresh vegetables and flowers, for hydrophonics gardening, and for storage of roots and bulbs. It is also used in the manufacturing of insulator sheets for houses. Moss industries in France manufacture moss carpets in various sizes (*Figure* 2). They are easy to fix along the roads, lawns, play grounds, etc. In Sri Lanka, a wide range of eco-friendly products such as coir pots, coir fiber pith (coco peat), moss sticks, hanging wire baskets and basket liners are made using bryophytes (*Figure* 3).

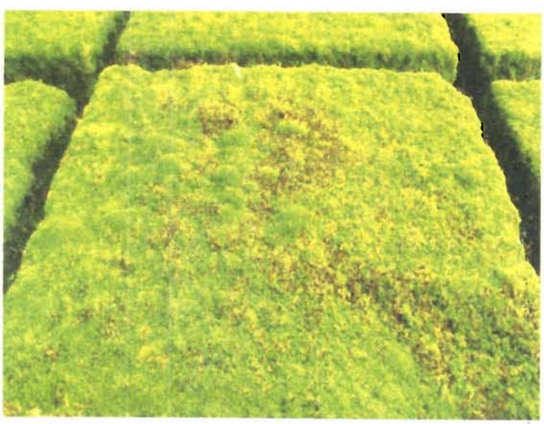


Figure 2. Moss carpets.
Courtesy: Michel Chiaffredo, M/S Bryotech, France.

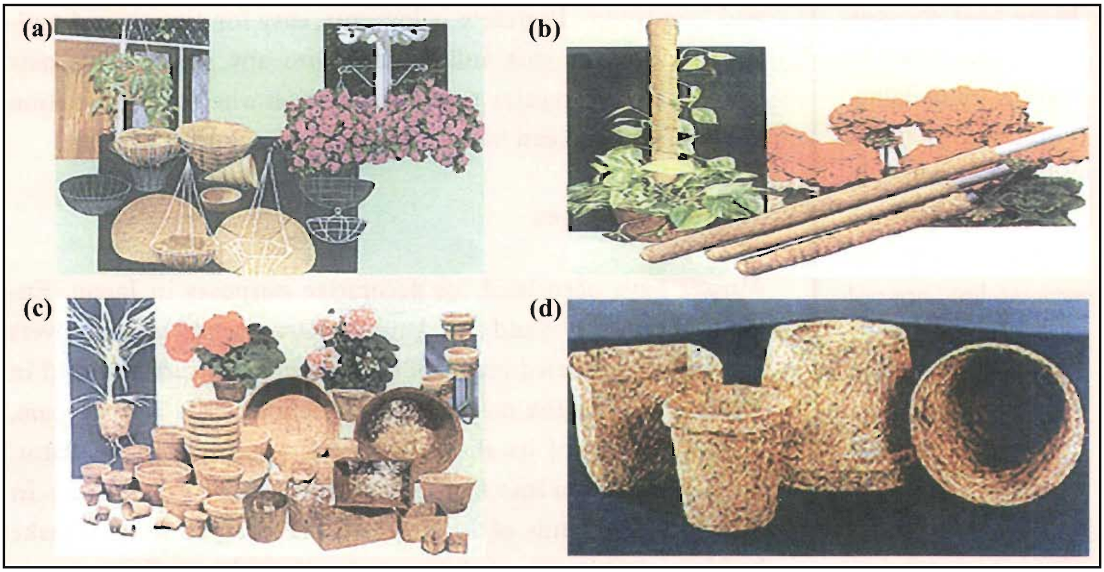


Figure 3. Various products made from bryophytes: (a) hanging wire baskets (b) moss sticks (c) basket liners (d) coir pots.
Reproduced with permission. Source: http://www. rex. industries @ lanka.com.ltd

Bryophytes as Fuel

Liverworts and mosses have long been tried and used as a fuel in developed countries like Finland, Sweden, Ireland, West Germany, Poland and Soviet Union. Peat is suitable for production of low and intermediate BTU gas as well as hydrogen, ethylene, natural gas, methanol and Fisher Tropsch gasoline. Peat mosses are best suited for the production of methane, and peat is likely to become an important source of fuel for production of heat, methane, or electricity in the future. Peat has rapid regeneration, can be easily harvested, has low sulfur content, and its heating value is superior to that of wood.

House Construction

In parts of the globe where woody plants are scarce and bryophytes common, these tiny plants are used in the construction of houses and their furnishings. At Kapkot in the Himalayas, villagers use moss mats with shrubs, grasses, and bamboo to make a pharki, a kind of door placed at the openings of their temporary huts. *Sphagnum* peat has been developed as a new construction material through the use of binders for solidification and strengthening, resulting in new products like 'peatcrete'

In parts of the globe where woody plants are scarce and bryophytes common, these tiny plants are used in the construction of houses and their furnishings.

In the past, mosses were used as material for bedding, packing, plugging and stuffing owing to their soft elastic texture, and also because they are not easily attacked by insects and micro-organisms.

and 'peatwood'. Peatcrete is low cost, easy for sawing and nailing, and can be cast and molded into any shape. This new product is easy to carry to any destination where transportation is a problem and can be used in building material.

Household Uses

Mosses have been used for decorative purposes in Japan, England, France, Finland and America. Ornamental water flowers are made from dried plants of *Climacium japonicum* and sold in Japan. Probably the most useful household moss is *Sphagnum,* largely because of its absorbent property and as an insulator. Mosses are woven into mats and sold in many parts of India. In the alpine highlands of the Northwest Himalayas, Indians make bedding, mattresses, cushions and pillows by stuffing mosses into coarse linen sacks or by spreading them on the muddy floor. The Himalayans also use mosses as insect repellents when storing food. Local mosses and liverworts are dried, made into a coarse powder that is sprinkled over grains and other goods to be stored in containers. Several insect anti-feedants have now been found in diverse bryophytes, making this group of plants a useful source of insecticides and insect repellents.

Sphagnum is now even being used for cushioning the foot and absorbing moisture and odors in hiking boots. In Germany, *Sphagnum* mixed with wool has been used to prepare a cheap cloth. Women in the villages of Kumaon, India, make head cushions of mosses (*Hylocomium, Hypnum, Trachypodopsis*) to carry vessels of water by stuffing the mosses into cloth sacks. In the past, mosses were used as material for bedding, packing, plugging and stuffing owing to their soft elastic texture, and also because they are not easily attacked by insects and micro-organisms. In India, *Sphagnum, Hypnum cupressiforme, Macrothamnium submacrocarpum, Neckera crenulata, Trachypodopsis crispatula* and *Thuidium tamariscellum* are used for packing of apples and plums in the western Himalayas. Nurserymen in India often use wet *Sphagnum* for sending or supplying live plants.

Medicinal Uses

The Chinese and the native Americans have used various moss species like *Philonotis, Bryum, Mnium,* crushed into a kind of paste and applied as a poultice. In India, the burned ash of mosses mixed with fat and honey is used as an ointment for cuts, burns and wounds in the Himalayan region. The liverwort *Marchantia polymorpha* is also used as a medicine for boils and abscesses, perhaps because the young archegoniophore resembles a boil when it first emerges from the thallus. The rosette-forming *Riccia* spp., are used as an external application to cure ringworm. Chinese traditional medicine names 40 kinds of bryophytes that have been used to treat illnesses of the cardio-vascular system, tonsillitis, bronchitis, tympanitis, cystitis, as well as skin diseases and burns. It has been shown that an extract of *Rhodobryum giganteum* can increase aorta blood transit by upto 30% in animals. Transgenic *Physcomitrella* are now being used to produce 'blood-clotting factor IX', for the treatment of 'haemophilia' B. Preparations of calcined peat have long been regarded as effective and cheap germicides; peat water possesses astringent and antiseptic properties. 'Sphagnol', a distillate of Peat Tar, is useful in eczema, psoriasis, pruritus, hemorrhoids, chilblains, scabies, acne and other forms of skin diseases, and is also beneficial for allaying irritation arising from insect bites.

Liverworts are not susceptible to fungal diseases, and antimicrobial activity has been seen in extracts of *Reboulia* and *Pallaviciania,* possibly due to lunularic acid, found in liverworts but not in mosses.

One of the features that helps bryophytes survive and maintain their place in today's flora is their content of biologically active compounds. These protect the otherwise delicate plants not only from fungi and other microorganisms but also from insects and slugs. In a way, these biochemical compounds make up for the lack of a thick cuticle and bark in bryophytes.

Liverworts are not susceptible to fungal diseases, and antimicrobial activity has been seen in extracts of *Reboulia* and *Pallaviciania,* possibly due to lunularic acid, found in liverworts but not in mosses. A few moss genera like *Atrichum, Dicranum, Minium, Polytrichum and Sphagnum* also possess antibiotically active substances. It was found that a methanol extract from *H. aduncus*

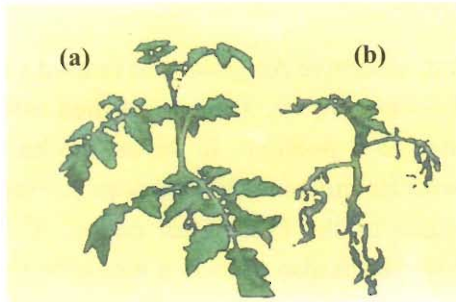


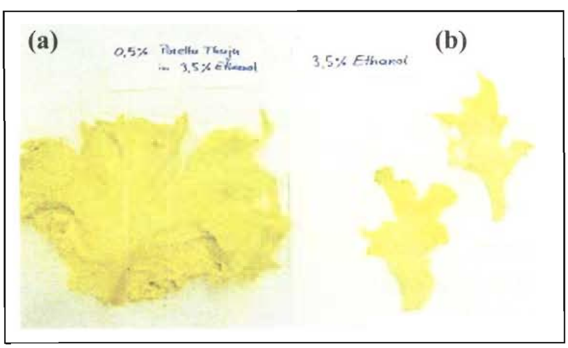
Figure 4. Antimicrobial activities of bryophytes: Effect of entire liverwort extract on tomato plant infected with Phytopthora infestans; (a) treated with extract (b) without extract.

inhibited the growth of pathogenic fungi *Botrytis cinerea, Rhizoctonia solani* and *Pythium debaryanum,* whereas petroleum-ether extracts of *Barbula* and *Timmiella* species were found to be active against both gram-positive and gram-negative bacteria. *Plagiochila stevensoniana* proved to inhibit dermatophytic organisms like *Trichophyton mentagrophytes, Candida albicans* and *Bacillus subtilis.* This antibiotic activity might be attributed to the presence of non-ionized organic acids and polyphenolic compounds. In the case of several bryophyte species, the active ingredients responsible for anti-microbial effects have been identified, e.g. Polygodial from *Porella,* Norpiguisone from *Conocephalum conicum,* and Lunularin from *Lunularia cruciata.* Green-house tests have shown that plants (tomato, pepper, cucumber, wheat) treated with liverwort extract were distinctly less affected (if at all) by fungus infections by *Phytophtora infestans* than untreated plants (*Figure* 4). However, as yet, these extracts have not actually been applied in agricultural settings.

Figures 4 and 5 reproduced with permission.
Source:www.bryologie.uni-bonn.de/english/contentGB/AktuellesGB/fungizidgb.htm

Many bryophyte extracts act like stomach poison on animal pests. The slug *Arion lusitanicus* was offered lettuce with liverwort extract and with pure solvent as control. The untreated (control) leaf was devoured completely (*Figure* 5b) whereas the leaf treated with liverwort extract remained untouched (*Figure* 5a). This leads us to the conclusion that liverwort extract is not only a potent fungicide and bactericide, but also a weak biocide (stomach poison) against animal pests.

Figure 5. Anti-feedant effect of bryophytes. (a) Leaf treated with liverwort extract remained untouched, whereas (b) the untreated (control) leaf was devoured completely by a slug.



Anti-leukemic activity has also been demonstrated in several compounds from leafy liverworts. A new enteudesmanolide, diplophyllin, was isolated from *Diplophyllin albicans* and *D. taxifolium*. Diplophyllin, having an alpha-methylene lactone unit, showed significant activity (ED50 4-6 μg/ml) against human epidermoid carcinoma (KB cell culture). Its optical enantiomer, derived chemically from the compound isoanantolactone, exhibited anticancer activity (ED50 20-37 μg/ml). Compounds from *Plagiochila fasciculata* (New Zealand) seemed to inhibit P388 cells (leukaemia).

During the first world war, the Germans used *Sphagnum* extensively for dressing wounds. *Sphagnum* pads are superior to cotton for dressing wounds as they absorb liquids 3-4 times as much as cotton, rendering frequent change of dressing unnecessary. Moreover, they are economical, cooler, softer and less irritating to the skin than cotton. A pad of *Sphagnum* moss absorbs the discharge in lateral directions, as well as immediately above the wound, and holds it until fully saturated in all parts of the dressing before allowing any to escape. For the preparation of the dressing, moss after being dried is carefully picked over and put up loosely in small, flat thin muslin bags (2 oz. of the moss to each bag, 10 inches by 14 inches).

Suggested Reading

[1] D K Saxena, in *Proceedings of XIII International Botanical Congress Abstracts*, 1981, p. 292, Sydney.

[2] J M Glime and D K Saxena, *Uses of Bryophytes*, Today and Tomorrow Printers and Publishers, New Delhi, India, 1990.

[3] D K Saxena and A Saxena, *Role of plant tissue culture in biodiversity conservation and economic development*, Gyanodaya Prakashan, Nainital, India, pp. 605-621, 2002.

[4] G Pant and S D Tewari, *Bryologist.*, Vol.92, pp.120-122, 1989.

[5] G Pant, *Indian J. Forestry*, Vol.4, No.3, pp. 186-190, 1981.

[6] K G Gupta and B Singh, *Res. Bull. Punjab Univ.*, Vol.22, pp. 237-239, 1971.

[7] H Ando, *Bull Biol. Soc. Hiroshima Univ.*, Vol.7, No. 7, pp. 23-26, 1957.

[8] H Ding, *Medical spore-bearing plants of China, Shanghai*, p. 499, 1982.

Address for Correspondence
D K Saxena and Harinder
Department of Botany
Bareilly College
Bareilly 243 005, UP, India.
Email: dksaxena@hotmail.com