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Bryophytes - The Ignored Medicinal Plants

Afroz Alam*[1], Vinay Shrama[1], K. K. Rawat[2] and P. K. Verma[3]
[1]Department of Bioscience and Biotechnology, Banasthali University, Rajasthan-304022
[2]CSIR-National Botanical Research Institute, Rana Pratap Marg, Lucknow-226 001, India
[3]Shifting Cultivation Division, Rain Forest Research Institute, Sotai Ali, Jorhat-785001, Assam, India

*Corresponding author's
email: afrozalamsafvi@gmail.com

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Abstract

Information about the occurrence of antibiotic substances in bryophytes and the medicinal use of bryophytes are sporadic, particularly in India, in comparison to developed countries. Despite of a long history of medicinal use of bryophytes by various tribal and local communities across the world, their significant utilization in medicines is still a dream due to lack of concise ethnobotanical information, scarcity of material, degrading habitats etc. Present article is an attempt to create awareness about this group of plants.

Introduction

Humans recognize their environs at a certain spatial and temporal scale. Unlike other gigantic plants, most measurements of morphological features in bryophytes (Lilliputians/amphibians of plant kingdom) are in micrometers or millimeters, centimeters at the largest. They also lie on the less important and low visible places and hence they are often unnoticed by humans. Therefore, bryophytes are less noticeable than vascular plants and remain underexplored in many aspects including their medicinal value. In comparison to other plant groups, bryophytes are exploited in lesser amount for the varied necessities of human but the conventional use of species on the basis of 'doctrine of signatures' is an old practice among native tribes.

Seville Flowers[1] was the first person who introduced the term "ethnobryology" in an article about the uses of bryophytes.[2] Despite its 56 years old existence, this term has not entered trendy conversation in any of the biological or the ethnobiological sciences. In his paper Harris[2] considered two main factors for its limited use, one is that there are not much ethnobotanical uses of bryophytes, and the other is that there may be a prejudice on the part of ethnobotanical researchers to focus on large plants of other groups for their easy availability and identification. As a result, although the ethnobotanical uses of bryophytes are interesting to most bryologists, it is both uncommon and somewhat difficult to find any ethnobryological reports in the literature. Indicating this Henry S. Conrad[3] wrote: "Perhaps no great group of plants has so few uses, commercial or economic, as the mosses."

In last few decades the medicinal value of bryophytes has received interest to a great extent and many chemicals and secondary metabolites have been isolated from many bryophytes, Recently, Harris compiled and documented a comprehensive account on the medicinal use of bryophytes in diverse parts of the world and listed about 150 species.[2] According to him the medicinal uses of bryophytes are mostly explored by Native North Americans (28%), followed by Chinese (27%). But in India this figure is not very encouraging. However, the first ever description on the traditional and cultural uses of bryophytes in the Indian region, along with a detailed description and illustration, originally appeared in *Hortus Malabaricus*.[2]

Three plants are very significant for their medicinal importance viz. *Marchantia polymorpha*, a cosmopolitan liverwort, which has been used in the cure of pulmonary tuberculosis[4] and liver related ailments. The treatment of liver diseases with this particular plant represents an exceptional illustration of the interested old "*Doctrine of Signatures* " which taught that the medicinal uses to which plants could best be put are shown by the shape and structure of the plants. Hence, *Marchantia* plants, because of their imaginary similarity to the liver, were believed to be helpful in the treatment of ailments of that organ[5, 6] and considered as a remarkable good herb for all the diseases of the liver and helps the tenderness in any part, and the jaundice as well.[7] Use of *Marchantia* to treat boil is also reported from India[8] due to resemblance of young archegoniophore with boil. Similarly, *Riccia* species were used to treat ringworm due to resemblance of its habit with the ring made by infections.[9] Representatives of several moss genera have also been reported having medicinal properties.[10] A tea prepared of *Polytrichum commune* is believed to help in liquefying kidney and gall bladder stones.[11] Oil extracted from the calyptras of the same was used by ladies to strengthen their hairs due to long hairs on calyptra.[12-13] Likewise dried *Sphagnum* (Peat moss) is on hand for sale in various herb shops in China. The whole-plant is boiled in water, and the decoction is believed to be used to cure acute hemorrhage and eye diseases.[14] According to various reports, peat tar extracted from peat having antiseptic and preservative properties. Sphagnol, a distillate of peat tar, is thought to be firmly recognized as helpful for the treatment of several skin diseases and has also been suggested to relieve the itching of insect bites and even to prevent them.[15] An ointment was made by the Alaska Indians, used for cuts, by mixing *Sphagnum* leaves with tallow or grease.[16] *Sphagnum* particularly has much more medical significance than other mosses, mainly because of its enormous absorbent capacity and its slight antiseptic properties. *Sphagnum* was first used surgically in a large way all through the Russo-Japanese warfare when the Japanese used it comprehensively as a first-aid dressing. Undeniably, it was found to make a better dressing than cotton.[17] According to Porter,[18] *Sphagnum* has the following advantages over cotton for surgical use: (a) the moss soaks up liquids more speedily, about three folds as fast, and in quantity three to four folds as great as cotton; (b) *Sphagnum* holds liquids for considerable longer periods, hence reducing the frequency of the dressing requires to be changed; (c) *Sphagnum* distributes imbibed liquids more homogeneously throughout its mass; (d) dressings of *Sphagnum* are cooler, softer and less annoying than those made with cotton; and (e) these dressings can be produced more swiftly and economically in urgent situation.

Beside *Marchantia*, *Polytrichum* and *Sphagnum*, there was a shortage of information regarding the existence of antibiotic substances in bryophytes. However, Watt[19] had referred to the medicinal application of *Marchantia polymorpha*,[20] *Fegatella conica* [=*Conocephalum conicum*] and a few species of *Jungermannia*, *Riccia* and *Anthoceros*, while Wren[21] reported only *Polytrichum juniperum* Wild. in this regard. According to Hartwell,[22] extracts of *Polytrichum commune, Marchantia polymorpha*, *M. stellata* and another unidentified species of *Polytrichum* has anti-tumor properties. Usually bryophytes are considered comparatively free from attack by parasitic microorganisms. However, a few reports of infection of bryophytes by fungi are exist, although the infected plants constitute only a small fraction of the large number of bryophytes known so far.[23] The cause of this may be anatomical, immunological or may be due to the presence of antimicrobial activities or other factors. There is a need for more information on following aspects of bryophytes:

Use of bryophytes as antimicrobial and antifungal agents

Antibiotic activity of bryophytes has drawn the attention of botanists and micro-biologists only in last few years. Regarding antimicrobial activities miscellaneous reports are there such as; Hayes[24] found aqueous extracts of *Conocephalum conicum* to be inactive against selected microbes. Madsen and Pates[25] studied 8 bryophytes of which *Conocephalum conicum*, *Dumortiera hirsuta*, *Sphagnum portoricense* and *S. strictum* were reported active against selected microbes. The former two were active against *Candida albicans*, and the species of *Sphagnum* was reported inhibitory against *Staphylococcus aureus* and *Pseudomonas aeruginosa*. Ramaut[26] showed that extracts of *Sphagnum* inhibit growth of *Sarcina lutea*. Antiseptic properties of the bogs have been recognized to the acidity of the *Sphagnum* extract and to the anaerobic conditions present therein. McCleary et al.[27] examined 12 species of mosses of which *Anomodon rostratus* and *Orthotrichum rupestre* inhibited the growth of *Micrococcus flavus*, *M. rubens*, *Streptococcus pyogenes* and *Candida albicans*. Ethanolic extracts of *Mnium cuspidatum* produced antibiotic substances active only against *Micrococcus flavus*. Later McCleary and Walkington[28] primarily studied the activity of 50 species of mosses belonging to 32 genera against *Gaffkya tetragena* and *Streptococcus aureus*. Eighteen species showed moderate to strong activity against one or both bacteria, 7 others possessed a slight but positive activity. Noticeable activity was shown by the genera *Atrichum*, *Mnium*, *Polytrichum* and *Sphagnum*. Further studies against larger number of test organisms revealed that *Atrichum undulatum* possessed inhibitory activity against 9 test organisms. Mosses like *Tortula ruralis* and *Dicranum scoparium* were next in order, inhibiting 6 test organisms. Wolters[29] studied antifungal activity of 18 species of bryophytes in 9 families, 2 of which under Jungermanniales and 16 under mosses. *Plagiothecium denticulatum*, *Pogonatum aloides* and *Diplophyllum albicans* were mainly remarkable in this context. Gupta and Singh[30] reported antibacterial activities of petroleum ether extracts of 2 species of mosses, *Barbula* and *Timella*, against 33 bacterial species belonging to Gram positive, Gram negative and acid-fast bacteria. Ding[31] and Ando[32] reported the use of around 40 species of bryophytes by Chinese as crude drug including mainly *Frullania tamarisci*, *Reboulia hemispherica*, *Conocephalum conicum*, *Marchantia polymorpha*, *Sphagnum* spp., *Weissia controversa*, *Funaria hygrometrica*, *Bryum argenteum*, *Rhodobryum roseum*, *Climacium dendroides* and *Polytrichum commune*.

Bryophytes are also known to be traditionally used for burns, cuts, wounds and skin disease which suggests that they may probably protect the skin and open wounds from microbial pathogens.[33-35] Kumar et al.[36] reported the use of *Plagiochasma appendiculatum* by the people of Gaddi tribe of Himachal Pradesh India, for the treatment of cuts, wounds and burns. Singh et al.[37] studied the antimicrobial, wound healing and antioxidant activity of the same. Later, they studied the antibacterial activity of four bryophytes viz., *Plagiochasma appendiculatum* L. et L., *Conocephalum conicum*, *Bryum argenteum*, *Mnium marginatum*, for the treatment of burn infections. Similarly use of *Philonotis*, *Bryum*, *Mnium* spp. are also reported to be used to treat pain of burns, to cover bruises and wounds and as padding under splints in setting broken bones.[1]

Polytrichum juniparicum was also reported to be used to relieve burn by northern Cheyenne Indians of Montana.[38]

On the basis of these results in bryophytes, there has been a surge in awareness regarding bryophytes by plant chemists at present. Consequently, several unsaturated lipids, fatty acid esters, flavonoids, triterpenoids, phenolics etc. have been reported during the last decade.[39-42] However, unconventionally, in a mammoth task Cambie et al.[43] screened 251 mosses of New Zealand and found no evidence of existence of alkaloids, leucoanthocyanins, saponins, triterpenes and steroids from these mosses. Unfortunately, the antimicrobial activity of these compounds has not been tested. Thus, it is evident that relatively few species of bryophytes have been examined so far for occurrence of antibiotic activity.

Unlike mosses, the plants of class Hepaticae (Liverwort) hold oil bodies in their cells which are effortlessly extracted with organic solvents. The liverworts are plants of medicinal value and are said to have definite biological activity and effect.[44-46] Generally, these are not affected by insects, slugs, snails and other miniature fauna. In addition, a number of liverworts cause severe allergenic contact dermatitis and allelopathy. A number of taxa of this class have extensively been utilized as medicinal plants in many parts of India, to heal burns, external wounds, bruises etc. A few liverworts show distinctive aromatic smell and a strong hot and pungent or saccharine-like taste. It has been confirmed that most of the hepaticae contain mainly lipophilic mono-, sesqui-, and diterpenoids, aromatic compounds (bibenzyls, bis-bibenzyls, benzoates, cinnamates, long-chain alkyl phenols, naphthalenes, phthalides, isocoumarins), and acetogenins which constitute the oil bodies. The biological activities of liverworts are because of these substances. At present, over 400 new compounds have been isolated and their structures elucidated.[47-50] The biological characteristics of the terpenoids and aromatic compounds isolated from the liverworts contain: (1) distinctive odors; (2) tanginess and sourness; (3) allergenic contact dermatitis; (4) anti-HIV, cytotoxic and DNA polymerase β inhibitory; (5) antifungal and antimicrobial activity; (6) anti-feedant activity against insects, mortality, and nematocidal activity; (7) superoxide anion radical release inhibitory activity; (8) 5-lipoxygenase, calmodulin, hyaluronidase, cyclooxygenase inhibitory action, and nitric oxide (NO) production inhibitory action; (9) piscicidal and plant growth inhibitory action; (10) neurotrophic activity; (11) muscle relaxing activity; (12) cathepsins B and L inhibitory activity; (13) cardiotonic and vasopressin antagonist activity; (14) antiobesity activity.

In India, some plants have been studied for their characteristic activity. Moss taxa like *Bryum argenteum* has antipyretic, antirhinitic activity; antidotal and used for bacteriosis in all bryo-geographical region of India. *Cratoneuron filicinum* is used for malum cordis (heart disease) in Western Himalayas. *Fissidens laxitextus* used for its diuretic activity, for improved hair growth, burns, and choloplania (jaundice, icterus) in Eastern Himalayas. *Funaria hygrometrica* used for hemostatis, pulmonary tuberculosis, hematemesis, bruises, athlete foot dermatophytosis (dermatomycosis, dermomycosis) in almost all bryogeographical region of India. *Leptodictyum riparium* is a potent antipyretic and also used for choloplania and uropathy by the tribes of Western Himalayas. *Mnium cuspidatum* is used by local peoples of Western and eastern Himalayas for the treatment of nosebleed and hematostasis. Likewise, *Oreas martiana* used for pain, external wounds, epilepsy, hemostasis, menorrhagia, and neurasthenia (nervosism, nervous exhaustion) in Western and Eastern Himalayas. *Philonotis fontana* have antipyretic and antidotal activity and also used for adenopharyngitis in South India. *Plagiopus oederi* is a sedative and used for epilepsy, apoplexy, and cardiopathy in Western Himalayas. *Polytrichum* species are known for their diuretic activity and for enhanced growth of hair in all bryo-geographical region of India. *Rhodobryum giganteum* is also antipyretic, diuretic, and antihypertensive hence used for sedation, neurasthenia, psychosis, cuts, cardiopathy, and expansion of heart blood vessels by the peoples of Himalayas and South India. Another species, *Rhodobryum roseum* is an excellent sedative and used for neurasthenia and cardiopathy in both the Himalayas. *Taxiphyllum taxirameum* is an antiphlogistic and used for hemostasis and external wounds all over India.[51] *Entodon myurus* has also been reported for its antibacterial activity against *Enterobacter aerogenes* and *Klebsiella pneumoniae* from India.[52] Singh et al.[53] provided a summarized account of 28 species of bryophyte species being used in India for their medicinal value. However, it is clearly evident that this particular group of plants is least known for their medicinal properties, especially in India and other south Asian countries.

A number of liverworts viz. *Bazzania* spp., *Dumortiera hirsuta*, *Conocephalum conicum*, *Pellia endiviifolia*, *Marchantia polymorpha*, *M. furcata*, *Plagiochila* species, *Porella vernicosa* complex, *P. platyphylla*, and *Radula* species show antimicrobial activity.[48, 54] Marchantin A from many species of *Marchantia* like *M. chenopoda*, *M. polymorpha*, *M. paleacea* var. *diptera*, *M. tosana* and *M. plicata* shows antibacterial activity against *Acinetobacter calcoaceticus* (MIC 6.25 µg/ml), *Alcaligenes faecalis* (100 µg/ml), *Bacillus cereus* (12.5 µg/ml), *B. megaterium* (25 µg/ml), *B. subtilis* (25 µg/ml), *Cryptococcus neoformans* (12.5 µg/ml), *Proteus mirabilis*, *Pseudomonas aeruginosa*, *Enterobacter cloacae*, *Escherichia coli*, *Salmonela typhimurium* (100 µg/ml), and *Staphylococcus aureus* (25 µg/ml).[55] They also have antifungal activity against *Alternaria* sp., *Aspergillus fumigatus* (MIC 100 µg/ml), *A. niger* (25-100 µg/ml), *Candiada albicans*, *Microsprorum gypseum*, *Penicillium chrysogenum* (100), *Piricularia oryzae* (12.5 µg/ml), *Rhizoctonia solani* (50 µg /ml), *Saccharomyces cerevisiae*, *Sporothrix schenckii* (100 µg/ml), and the dermatophytes *Trichophyton mentagrophytes* (3.13 µg/ml) and *T. rubrum* (100 µg/ml). Sacculatal, isolated from *Pellia endeviifolia* showed strong antibacterial activity against

Streptococcus mutans (dental caries) at LD50 8 µg/ml, however, polygodial is less active (100 µg/ml) than sacculatal.[56]

Biologically active substances

Various species of bryophyte in fact manufacture broad-range antibiotics. Their usage in dressings, diapers production, and other human medicinal applications is recognized in various parts of the world such as Asia, Germany,[57] Brazil,[58] England,[59] China[7, 60] and India.[61] Occurrence of unique odors is one such hint which confirmed the presence of exclusive and potentially pharmaceutically important chemicals in bryophytes. This is particularly spot on for liverworts e.g. *Isotachis japonica, Geocalyx graveolens* has a turpentine-like smell, *Leptolejeunea* and *Moerckia* are specifically aromatic,[62] species of *Solenostoma* scent like carrots, *Lophozia bicrenata* has a pleasing odor, *Conocephalum conicum* scents like mushrooms and *Plagiochila rutilans* smells like mint due to numerous menthane monoterpenoids.[63] These are basically a combination of many compounds, including monoterpene hydrocarbons such as α-pinene, ß-pinene, myrcene, alpha-terpinene, camphene, sabinene, limonene, fatty acids, and methyl esters (benzyl benzoate, benzyl cinnamate, and -phenylethyl cinnamate) of low molecular weight.[64, 65]

Scientists have found innumerable kinds of biological activity in compounds from bryophytes. Even in a single species, one might find multiple kinds of activity. For example, the liverworts *Plagiochasma japonica* and *Marchantia tosana* exhibit antitumor activity, antifungal and antimicrobial activity, inhibition of superoxide release, inhibition of thrombin activity, and muscle relaxation.[66] As is often the case with herbal medicine, the effect of the total extract is better than that of the isolated compounds, perhaps due to a synergistic effect.[57]

Inhibitory activity over superoxide release

Surplus superoxide anion radical (O_2^-) in organisms originates various angiopathies, such as arterial sclerosis and cardiac infarction. Infuscaic acid (clerod-3,13(16)-14-trien-17-oic acid) and plagiochilal B from *Jungermannia infusca* hinder the release of superoxide from rabbit PMN at IC50 0.07 and 6.0 µg/ml, respectively and from guinea pig peritoneal macrophage induced by formyl methionyl leucyl phenylalanine (FMLP) at IC50 40 µg/ml, and 25.0 µg/ml respectively.[67] The same activity (IC50 7.5 µg/ml) has been reported in cyclomyltaylyl-3-caffeate from *Bazzania* sp. Other sesquiterpenoids, plagiochilide isolated from *Plagiochila fruticosa*, norpinguisone from *Porella vernicosa*, bicyclogermacrenal from *C. conicum,* herbertenediol and infuscaside A, and infuscaside B from *J. infusca*, and perrottetianal A from *Porella perrottetiana* also inhibit release of superoxide from guinea pig peritoneal macrophage (IC50 12.5–50 µg/ml).[48] Radulanin K from *Radula javanica* inhibits the release of superoxide anion radical from guinea pig macrophage (IC50 6 µg/ml) (Toyota et. al., 1990). Polygodial and sacculatal also show superoxide anion radical release inhibition at 4.0 µg/ml from guinea pig peritoneal macrophage.[56]

Antiviral Activity

In New Zealand bryophytes have used to treat venereal ailment by packing wet plants on the infected organs.[57] It is an assumption with full conviction that in future even viruses may be cured by extracts of mosses, For example, Klöcking et al.[68] found that at least some peat humic acids have antiviral activity against herpes simplex virus types 1 and 2, interfering primarily with the adsorption of viruses to host cells. *Sphagnum* produces several active humic acids against virues, and *Camptothecium* extracts can inhibit growth of the poliovirus.[69]

Anti-tumor Properties

Belkin et al.[70] reported anticancer action against Sarcoma 37 in mice, using extracts of *Polytrichum juniperinum*. In 1976, Adamek[71] reported that peat preparations hold some guarantee against some types of human cancer. In 1977, Ohta et al.[72] reported that diplophyllin, isolated from the liverworts *Diplophyllum albicans* and *D. taxifolium*, shows significant activity (ED50 4-16 µg/ml) against human epidermoid carcinoma.

Laxatives and Diuretics

Hu used *Ploytrichum commune* as diuretic and laxative agent.[7] He also used this plant as detergent and hemostatic agent.

Gynecology

Turner et al.[73] used *Ploytrichum commune* as an assist in gynecology. *Sphagnum* is helpful in speeding up the process of labor. Beside this *Sphagnum* has also been used as a contraceptive to obstruct the access of sperm, along with grass, sponge and other fiber.[74]

Neurotrophic action

Bioactive compounds like Plagiochilal B and plagiochilide from *Plagiochila fruticosa* demonstrate not only acceleration of neurite sprouting but also augmentation of choline acetyl transferase activity in a neuronal cell culture of the fetal rat cerebral hemisphere at 10^{-5} M.[50, 67] Plagiochin A also exhibits the same activity at 10^{-6} M.[75] Two bitter diterpene glucosides, infuscaside A and B, show neurite bundle formation at 10^{-7} M.[56]

Muscle relaxing drugs

Marchantin A and the associated cyclic bis-bibenzyls are structurally analogous to bis-bibenzyl-isoquinoline alkaloids such as *d*-tubocurarine, which are pharmacologically important muscle relaxing active drugs. Amazingly, marchantin A and its trimethyl ether also confirm muscle relaxing activity.[76] Nicotine in Ringer solution effects utmost contraction of rectus abdominis in frogs (RAF) at a concentration of 10^{-6} M. After pre-incubation of marchantin- A trimethyl ether in Ringer solution, nicotine (10^{-8}–10^{-4} M) was added. At a concentration of 10^{-6} M, the contraction of RAF decreased by about 30%. *d*-Tubocurarine demonstrated similar effects as does with acetyl choline.[76] Although the mode of action of marchantin- A and its methyl ether in effecting muscle relaxation is still mysterious, it is interesting that these cyclic bis-bibenzyls containing no nitrogen atoms, originates concentration-dependent decrease of contraction of RAF. Marchantin A and its trimethyl ether also had muscle relaxing activity *in vivo* in rats.

Cardiotonic and vasopressin antagonist action

Marchantin A was reported as potent cardiotonic. Prenyl bibenzyl from *Radula perrottetii* indicates vasopressin antagonist activity (ID50 27 µg/ml). However, 2-geranylbibenzyl from the same liverwort did not show VP antagonist activity.[48] Mosses also contain polyunsaturated fatty acids that are already known to have important potentials in human medicine, such as preventing atherosclerosis and cardiovascular disease, reducing collagen-induced thrombocyte aggregation, and lowering triacylglycerols and cholesterol in plasma.[77]

Lung diseases

Marchantia polymorpha thalli were used in the treatment of pulmonary tuberculosis.[5]

Liver X-receptor (LXR)_agonist and (LXR)_ antagonist activity

Liver X receptors (LXR) α agonist and (LXR) β share considerable sequence homology and numerous functions react to the same endogenous and synthetic ligands and play vital roles in maintaining lipid homeotasis. Riccardin C and Riccardin F, isolated from the liverwort *Reboulia hemisphaerica* function as an LXRαagonist/LXRβ antagonist and an LXRα antagonist, respectively.[78] Riccardin C efficiently enhances cholesterol efflux from THP-1 cells. This compound may provide a new tool for identifying subtype function and drug development against anti-obesity.

Treatment of skin

Local people of Himalayan regions use a mixture of moss ashes with honey and little fat to heal cuts, burns and injuries. *Marchantia polymorpha* and *Marchantia palmata* are used to treat abscesses and boils.[79,80] In other parts of the world *Polytrichum juniperum, Bryum, Mnium* and *Philonotis* are used as paste in the treatment of burns, pain, bruise and wounds.[1]

Filters

Species of *Herbertus*, *Anomodon*, *Entodon*, *Hypnum*, *Scapania* and *Meteriopsis* wrapped in a cone of *Rhodobryum campanulatum* leaves, to serve as smoking filters by the natives of Kumaun Himalayas.[33]

Transgenic Pharmaceutical Production

Bryophytes have indeed finally broken through the vanguard of modern medicine! One benefit of *Physcomitrella patens* is its ability to grow in a "bioreactor"[81-82], a fermenter in which only water and minerals are needed to cultivate the moss, certainly in the presence of light and CO_2 (Greenovation). Among its many assets, *Physcomitrella patens* is able to produce human proteins[81] and is the solitary plant being used to produce the blood-clotting factor IX for pharmaceutical use. Bryophytes offer the researchers, and the biotechnology based company, numerous advantages over higher plants. They can be grown fast devoid of antibiotics, hence avoiding the hazard of contagion of the final product. The moss is quite small and thus is cultured only in the lab with modest risk of the transgenic plants escaping into the environment. But the real advantage comes from the dominant gametophytic generation of mosses as contrasting to the prevailing sporophyte of the tracheophytes. Accordingly, mosses are the only plants known to have a elevated occurrence of homologous recombination. In addition, the highly complex moss system, contrast to bacteria and fungi, allows a much wider assortment of expression than is possible in those systems. Thus, mosses are enormously valuable as production systems for targeted substances that can be produced through genetic engineering.

Conclusion

Bryophytes are source of many incredibly interesting and useful bioactive compounds. The majority of the compounds reported in the bryophytes are lipophilic terpenoids (mono-, sesqui-, and diterpenoids) and fragrant compounds. Few of them are nitrogen- or sulfur-containing compounds.[83-85] It is remarkable that most of the sesqui- and diterpenoids reported in liverworts are the enantiomers of those reported in higher plants. Mono- and sesquiterpenoids are very unusual in mosses and hornworts, however, di- and triterpenoids have been isolated from certain mosses. Presently, only about 5 % of the total bryophytes have been studied chemically. Hence, there is an insightful call for their proper assessment regarding their useful chemical constituents and activities. India, being one of the main centers of bryo-diversity is still at the back in applied bryological research and therefore need some serious efforts.

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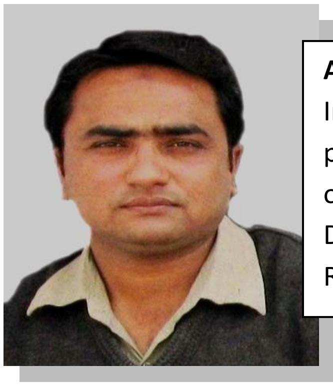

Afroz Alam, Ph. D., has over 50 research publications in prestigious International and National Journals and two text books with reputed publication houses to his credit. He is life member of various associations of Plant Sciences. Presently, he is working as Associate Professor in the Department of Bioscience and Biotechnology, Banasthali University, Rajasthan.

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