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# Bryophytes: A hidden treasure of antioxidants

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**Abstract**
The chemical compounds that can produce free radicals and leads to chain reactions that may damage the cells of organisms known as the oxidation and the compounds that inhibit the oxidation are known as antioxidants. Many diseases are caused by free radicals and oxidative stress is the major cause of diseases. It is due to the imbalance between the free radicals and antioxidants. To overcome this problem body needs antioxidants. These antioxidants either present endogenously or provided exogenous sources. Antioxidant compounds can be obtained from natural and synthetic sources. However synthetic antioxidants have been widely used to diminish oxidation, but it is dangerous to mankind. To control these imbalances plants have their own antioxidant protection system to reduce deleterious effect of ROS and have been used to protect themselves from many diseases. Therefore, there is a need of search of natural sources of antioxidants. Bryophytes a second largest group of plants are the good reservoir of different types of phytochemicals especially antioxidant compounds. The aim of the present review the literature related to the antioxidative property of bryophytes.

**Keywords:** bryophytes, antioxidant, phenolic compounds, ROS, DPPH

## Introduction
Bryophytes are found in moisture rich habitat or damp habitat of all ecosystems except marine ecosystem which play ecological roles in any ecosystem are significant [1]. The oldest land plant, bryophytes are rarely show any microbial attack due to the presence of phytochemical compounds in these plants. Bryophytes have been studied for phytochemical constitutes and many biological activities such as antioxidants, antifungal [2], antibacterial [3], cytotoxic, antitumor [4] and anti-inflammatory response [3], The antioxidant constituents present in bryophytes provide protection against cancer and many other diseases. Phytoactive compounds derived from many liverworts and mosses are major source of antioxidant.
Antioxidants are the compounds that reduce or inhibit the oxidation of compounds. Oxidation is the chemical reaction that damage the cells of organism by producing free radicals. The reactive oxygen species is originated during the various biological and physiological processes like respiration, photosynthesis and stress responses. When high amount of many free radicals and reactive oxygen species (ROS) are produced in human body, which harms to biomolecules such as proteins, carbohydrates, lipids and DNA. Due to this many chronic diseases may occur [5]. Antioxidants protect from harm arised by released ROS and associated protein damage, lipid peroxidation and breakage of DNA strand [6].

## Some Assay Methos used to Evaluate Antooxidants Activity of Plants
Antioxidants like flavonoids, phenolic acid, terpenoids (mono-, di-, sesquiterpenes) and tannins, exhibited broad range of biological activities, including anti-inflammatory, anticarcinogenic and antiatherosclerotic due to the antioxidant property [7].
Various types of assays are used to detect the antioxidant activity such as ferric reducing antioxidant power assay, total radical trapping antioxidant potential assay, ABTS (2, 2_-azinobis (3-ethylbenzthiazoline-6-sulfonic acid) radical scavenging method, thiobarbituric acid method, DPPH (1, 1-diphenyl-2-picrylhydrazine) radical scavenging activity, LPO method, hydroxyl radical scavenging activity, oxygen radical absorbance capacity assay, superoxide anion scavenging activity, FTC (Folin–Ciocalteu) method and reducing power assay [8].
Most commonly used methods are ABTS (2, 2`-azinobis (3-ethylbenzthiazoline-6-sulfonic acid) and DPPH (1, 1-diphenyl-2-picrylhydrazine) to find out antioxidant property.

## Antioxidative Properties of Bryophytes
Bryophytes are known as remarkable reservoir of natural products so they have been proven to be a rich source of antibiotics [9]. These plants have been commonly used in therapeutics as herbal medicine, especially in India and China to cure skin disorders and hepatitis [10]. Mosses are less explored for medicinal utility as compared to liverworts even though mosses are more diverse than liverworts. A high amount of secondary metabolites such as flavonoids, alkaloids, saponin, terpenoids, bibenzyls, fatty acids and acetophenols etc. have been identified from mosses. Liverwort plants have indicated high potential as chemotherapeutic agents. More than 220 aromatic compounds (naphthalenes, isocoumarins, long-chain alkyl phenols, phthalides, benzoates, bisbibenzyls, cinnamates, bibenzyls), 700 terpenoids (monoterpenoids, sesquiterpenoids diterpenoids) and acetogenins are isolated from liverworts that have been studied for their biological activities [11,12]. Liverworts and mosses possess a high level of antioxidant which can serve as future source for therapeutically and cosmetically significant compounds [9].
Different bryophytes have been explored to show their antioxidant activity. Some of these possess various kinds of flavonoid and phenolic compounds use for free radical

scavenging while others have more efficient antioxidant enzyme system. In one such study, due to inhibition of lipid peroxidation and increasing superoxide dismutase and catalase activity, extract of *Plagiochasma appendiculatum* showed antioxidant activity [13]. In another study on the moss *Sphagnum magellanicum*, many phenolic compounds such as vanillic, p-coumaric, salicylic acid, gallic, chlorogenic, caffeic and 3-4 hydrozybenzoic acid have been reported by using Reverse-phase high-pressure liquid chromatography [14]. Other studies characterised antioxidant peroxidase enzyme from liverwort *Marchantia polymorpha* and reported that peroxidase enzyme of *Marchantia polymorpha* and vascular plants was different [15]. The extract of *M. linearis* (cell suspension cultures) showed anticancerous activity against colon cancer cell lines due to presence of flavonoids [16].

Several factors like tissue type, altitude and seasons influenced antioxidant activity of bryophytes [17]. The extracts of *Eurhynchium striatum, Oxyteguste nuirostris* and *Rhynchostegium murale* have antioxidant property which was determined by ecological factor i.e., climate [18]. High level of free radical scavenging activity showed by *Eurhynchium striatulum* and *Homalothecium sericeum* [19]. and likewise, in *Bryum billardieri* [20]. Some secondary metabolites are produced by *Sanionia uncinate* (alpine moss) shows different kind of antioxidant activities such as superoxide radical scavenging activity, free radical scavenging activity and reducing power and also protect the plant from environmental stresses like high temperature, drought and UV radiations [21].

Other studies also disclosed that mosses have less content of total flavonoids as compared to liverworts. The high amount of this compound was found in epiphytic bryophytes than aquatic bryophytes [22]. Similarly, high antioxidant activities shown by the plant *Thuidium tamariscellum* due to the presence of considerable level of terpenoids [23].

*P. appendiculatum* had higher catalase and Guaiacol peroxidase activity than *Pellia endivaefolia*, but lower amount of total phenols, ascorbic acid, glutathione, proline and superoxide dismutase found in *P. appendiculatum* than *P. endivaefolia* [24]. For another study of antioxidant property in bryophytes, active compounds are isolated from ethyl acetate and ethanolic extract of *M. polymorpha* for screening of antioxidant property by using ABTS and DPPH assay. Ethyl acetate extract show higher antioxidant activity than ethanolic extract and these extracts contained luteolin as an important antioxidant compound. The methanolic extract of *Lepidozia bornensis* was used to study its antioxidant property and found that this has potential to induce apoptosis and cell cycle arrest in hormone dependent cells of breast cancer [10].

**Table 1:** Bryophytes showing antioxidant activity and antioxidant compounds.

| S. No. | Name of plant | Antioxidant compound | Extract | References |
|---|---|---|---|---|
| 1. | *Atrichum undulatum, Polytrichum formosum* | Three- and Tetra-oxygenated coumarin glucosides | Ethanol | [25] [26] [27] |
| | *Pleurozium schreberi,* | Apigenin, apigenin-7-rhamnoglucoside; acetylenic acids and lipids | | |
| | *Thuidium tamariscinum* | Triterpenes and lipids | | |
| 2. | *Barbula javanica* | Total Phenolic content | Ethanol | [28] |
| 3. | *Bryum billardieri* | Total phenolic compound- 38.18 gallic acid equivalence | Ethanol | [20] |
| 4. | *Bryum moravicum* | Phenolics | Aqueous | [29] |
| 5. | *Ceratodon purpureus* | Biflavonoids | Methanol | [30] |
| 6. | *Ceratodon purpureus, Dicranum polysetum, D. scoparium, Lucobryum glaucum, Mnium marginatum* | Total phenolics | Ethanol | [31] |
| 7. | *Cinclidotus fontinaloide, Palustriella commutata* | Phenolic compound | Ethanol, DI water | [32] |
| 8. | *Cryphaea heteromalla* | Phenolic compound, derivative of benzoic, caffeic, coumaric acids | Aqueous | [33] |
| 9. | *Cyathodium tuberosum* | Phenolics | Methanol | [34] |
| 10. | *Diplophyllum albicans, D. Taxifolium* | Diplophylline | - | [1] |
| 11. | *Eurhynchium striatum, Oxytegus tenuirostris* and *Rhynchostegium murale* | - | Ethanol, chloroform, methanol, aqueous | [18] |
| 12. | *Frullania muscicola* | *ent*-labdane diterpenoids (muscicolone) | Ether extract | [35] |
| 13. | *Funaria hygrometrica* and *Polytrichum commune* | Flavonoids | Methanol | [36] |
| 14. | *Homalothecium sericeum, Hypnum sericeum, Eurhynchium striatulum* | Phenolics | Ethanol | [19] |
| 15. | *Hypnum plumaeforme* | Antioxidant enzyme | - | [37] |
| 16. | *Lepidozia borneensis* | Phenolics, flavanoids | Methanolic extract | [10] |
| 17. | *Leptodictyum riparium* | - | Acetone | [38] |
| 18. | *Leucobryum uduncum* and *Campylopus schmidii* | Phenolics | Methanol | [39] |
| 19. | *Marchantia linearis, M. paleacea, Conocephalum conicum* | Total phenol, flavonoid and o-dihydric phenol | Methanol | [40] |
| 20. | *Marchantia polymorpha, Hypnum cupressiforme, Neckera complanata* | Phenolic acids (Rosamarinic acid, Quercetin, 4- hydroxy benzoic acid) | Methanol | [41] |
| 21. | *Pellia endivaefolia* and *Plagiochasma appendiculatum* | Phenolics | Methanol | [24] |

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|---|---|---|---|---|
| 22. | *Philonotis hastata* | Flavonoids | Methanolic | [42] |
| 23. | *Plagiochasma appendiculatum* | Flavonoids, saponins, sesquiterpenes | - | [13] |
| 24. | *Plagiochia beddomei* | Phenols and flavonoids | Methanol | [43] |
| 25. | *Plagiomnium ellipticum and Antitrichia californica* | Total phenol and flavonoids content | Ether | [44] |
| 26. | *Polytrichastrum alpinum* | Benzonaphthoxanthenones (ohioensins F and G) | Methanol | [45] |
| 27. | *Pseudoscleropodium purum* | Glutathione | - | [46] |
| 28. | *Sphagnum cuspidatulum, S. cuspidatum, S. junghuhniannum, Pogonatum cirratum* | Phenolic and flavonoid | Methanol, aqueous, ethanol | [47] |
| 29. | *Sanionia uncinata* | Total phenol content | Ethanol | [19] |
| 30. | *Sphagnum magellanicum* | Phenolic compound | Ethanol | [14] |
| 31. | *Thuidium tamariscellum* | Terpenoids | Petroleum ether, Chloroform, Ethyl acetate, Methanol | [23] |

## References


1. Saxena DK, Harinder. Uses of bryophytes. Resonance,2004:9(6):56-65.
2. Veljić M, Ćirić A, Soković M, Janaćković P, Marin PD. Antibacterial and antifungal activity of the liverwort (*Ptilidium pulcherrimum*) methanol extract. Archives of Biological Sciences,2010:62(2):381-385.
3. Ivanova V, Kolarova M, Aleksieva K, Dornberger KJ, Haertl A, Moellmann U *et al*. Sanionins: Anti-Inflammatory and Antibacterial Agents with Weak Cytotoxicity from the Antarctic Moss *Sanionia georgico-uncinata*. Preparative Biochemistry and Biotechnology,2007:37(4):343-352.
4. Shen J, Li G, Liu Q, He Q, Gu J, Shi Y *et al*. Marchantin C: a potential anti-invasion agent in glioma cells. Cancer biology & therapy,2010:9(1):33-39.
5. Cai Y, Luo Q, Sun M, Corke H. Antioxidant activity and phenolic compounds of 112 traditional Chinese medicinal plants associated with anticancer. Life Sciences,2004:74:2157-2184.
6. Patil SM, Kadam VJ, Ghosh R. *In vitro* antioxidant activity of methanolic extract of stem bark of *Gmelina arborea* Roxb. (Verbenaceae). International Journal of PharmTech Research,2009:1:1408-1484.
7. Chung KT, Wong TY, Wei CI, Huang YW, Lin Y. Tannins and human health: A review. Critical Reviews in Food Science and Nutrition,1998:38:421-464.
8. Ayoub ZE, Mehta AR. Medicinal plants as potential source of antioxidant agents: a review. Asian Journal of Pharmaceutical and Clinical Research,2018:11(6):50-56.
9. Edeoga HO, Eriata DO. Alkaloids, Tannin and Saponin Contents of Some Nigerian Medicinal Plants. Journal of Medicinal and Aromatic Plant Sciences,2001:23:344-349.
10. Bakar AM, Abdul Karim F, Suleiman M, Isha A, Rahmat A. Phytochemical constituents, antioxidant and antiproliferative properties of a liverwort, *Lepidozia borneensis* Stephani from Mount Kinabalu, Sabah, Malaysia. Evidence-based complementary and alternative medicine, 2015, 1-9.
11. Asakawa Y. Recent advances in phytochemistry of bryophytes acetogenins, terpenoids and bis(bibenzyl)s from selected Japanese, Taiwanese, New Zealand, Argentinean and European liverworts. Phytochemistry,2001:56(3):297-312.
12. Asakawa Y. Biologically active compounds from bryophytes. Pure and Applied Chemistry,2007:79(4):557-580.
13. Singh M, Govindrajan R, Nath V, Rawat AKS, Mehrotra S. Antimicrobial, wound healing and antioxidant activity of *Plagiochasma appendiculatum* Lehm. *et* Lind. Journal of Ethnopharmacology,2006:107:67-72.
14. Montenegro G, Portaluppi MC, Salas FA, Diaz MF. Biological properties of Chilean native moss *Sphagnum magellanicum*. Biological Research,2009:42(2):233-237.
15. Hirata T, Ashida Y, Mori H. A 37-kDa peroxidase secreted from liverworts in response to chemical stress. Phytochemistry,2002:55:197-202.
16. Krishnan R, Murugan, K. *In vitro* anticancer properties of flavonoids extracted from cell suspension culture of *Marchantia linearis* Lehm & Lindenb. (bryophyta) against sw 480 colon cancer cell lines. Indo American Journal of Pharmaceutical Research,2013:3:1427-1437.
17. Thakur S, Kapila S. Seasonal changes in antioxidant enzymes, polyphenol oxidase enzyme, flavonoids and phenolic content in three leafy liverworts. Lindbergia,2017:40:39-44.
18. Yayintas TO, Sogut O, Konyalioglu S, Yilmaz S, Tepeli B. Antioxidant activities and chemical composition of different extracts of mosses gathered from Turkey. AgroLife Scientific Journal,2017:6(2):205-213.
19. Erturk O, Sahin H, Erturk EY, Hotaman HE, Koz B, Oldemir O *et al*. The antimicrobial and antioxidant activities of extracts obtained from some moss species in Turkey. Herba Polonica Journal,2015:61(4):52-65.
20. LM M, Alonzo EAM, Lacerna MZT, Santiago JC. Total Phenol Content and Antioxidant Activity of *Bryum billardieri* Schwaegr. Microbiology,2012:2(3):345-353.
21. Bhattarai HD, Paudel B, Lee HS, Lee YK, Yim JH. Antioxidant activity of *Sanionia uncinata*, a polar moss species from King George Island, Antarctica. Phytotherapy Research,2008:22:1635-1639.
22. Wang X, Cao J, Dai X, Xiao J, Wu Y, Wang Q *et al*. Total flavonoid concentrations of bryophytes from Tianmu Mountain, Zhejiang Province (China): Phylogeny and ecological factors. PLoS One,2017:12(3):1-10.
23. Mohandas GG, Kumaraswamy M. Antioxidant activities of terpenoids from *Thuidium tamariscellum* (C. Muell.) Bosch. and Sande-Lac. A Moss. Pharmacognosy Journal,2018:10(4):645-649.
24. Sharma A, Slatbia S, Gupta D, Handa N, Choudhary SP, Langer A *et al*. Antifungal and antioxidant profile

of ethnomedicinally important liverworts (*Pellia endivaefolia* and *Plagiochasma appendiculatum*) used by indigenous tribes of district reasi: Northwest Himalayas. Proceedings of the National Academy of Sciences, India Section B,2015:85(2):571-579.
25. Jung M, Zinsmeister HD, Geiger H. New three- and tetraoxygenated coumarin glucosides from the mosses *Atrichum undulatum* and *Polytrichum formosum*. Z. Naturforsch,1994:49:697-702.
26. Marsili A, Morelli I. Triterpenes from *Thuidium tamariscifolium*. Phytochemistry,1970:9:651-653.
27. Vandekerkhove O. Uber die Verbreitung von Flavonoiden bei pleurokarpen Laubmoosen II. Apigenin and Apigenin-7-rhamnoglukosid bei *Pleurozium schreberi* (Willd.). Mitt. Z. Pflanzenphysiol,1980:100:369-372.
28. Vats S, Alam A. Antioxidant activity of *Barbula javanica* Doz. Et Molk.: A relatively unexplored bryophyte. Elixir Applied Botany,2013:65(3):20103-20104.
29. Pejin B, Bogdanovic-Pristov J, Pejin I, Sabovljevic M. Potential antioxidant activity of the moss *Bryum moravicum*. Natural Product Research,2013:27(10):900-902.
30. Waterman MJ, Nugraha AS, Hendra R, Ball GE, Robinson SA, Keller PA *et al*. Antarctic moss biflavonoids show high antioxidant and ultraviolet-screening activity. Journal of natural *products*,2017:80(8):2224-2231.
31. Chobot V, Kubicova L, Nabbout S, Jahodar L, Vytlacilova J. Antioxidant and free radical scavenging activities of five moss species. Fitoterapia,2006:77(7-8):598-600.
32. Yayintas OT, Alpaslan D, Karagul Yuceer Y, Yilmaz S, Sahiner N. Chemical composition, antimicrobial, antioxidant and anthocyanin activities of mosses (*Cinclidotus fontinaloides* (Hedw.) P. Beauv. and *Palustriella commutata* (Hedw.) Ochyra) gathered from Turkey. Natural product research,2017:31(18):2169-2173.
33. Provenzano F, Sanchez JL, Rao E, Santonocito R, Ditta LA, Borrás Linares I *et al*. Water extract of *Cryphaea heteromalla* (Hedw.) D. Mohr bryophyte as a natural powerful source of biologically active compounds. International journal of molecular sciences,2019:20(22):5560.
34. Ghatak A, Chaturvedi P, Kudale S, Desai N. Biochemical characterization and antioxidant potential of *Cyathodium tuberosum* kash collected from different environmental conditions. World journal of pharmaceutical research,2015:4(9):1616-1630.
35. Lou HX, Li GY, Wang FQ. A cytotoxic diterpenoid and antifungal phenolic compound from *Frullania muscicola*. Steph. Journal of Asian Natural Products Research,2002:4:87-94.
36. Hanif U, Ali HA, Shahwar D, Farid S, Ishtiaq S. Evaluation of Two Bryophytes (*Funaria hygrometrica* and *Polytrichum commune*) as a Source of Natural Antioxidant. Asian Journal of Chemistry,2014:26(14):4339-4343.
37. Sun SQ, He M, Cao T, Zhang YC, Han W. Response mechanisms of antioxidants in bryophyte (*Hypnum plumaeforme*) under the stress of single or combined Pb and/or Ni. Environmental monitoring and assessment,2009:149(1):291-302.
38. Basile A, Sorbo Conte B, Golia B, Montanari S, Castaldo C, Esposito S *et al*. Antioxidant activity in extracts from *Leptodictyum riparium* (Bryophyta), stressed by heavy metals, heat shock, and salinity. Plant Biosystems,2011:145(1):77-80.
39. Makajanma MM, Taufik I, Faizal A. Antioxidant and antibacterial activity of extract from two species of mosses: *Leucobryum aduncum* and *Campylopus schmidii*. Biodiversitas Journal of Biological Diversity,2020:21(6):2751-2758.
40. Mukhia S, Mandal P, Singh DK, Singh D, Choudhury D. *In-vitro* free-radical scavenging potential of three liverworts of Darjeeling Himalaya. International Journal of Pharmaceutical Sciences and Research,2014:5(10):4552.
41. Yayıntaş OT, Yılmaz S, Sokmen M. Determination of antioxidant, antimicrobial and antitumor activity of bryophytes from Mount Ida (Canakkale, Turkey). Indian Journal of Traditional Knowledge,2019:18(2):395-401.
42. Oyedapo OO, Makinde AM, Ilesanmi GM, Abimbola EO, Akiwunmi KF, Akinpelu BA *et al*. Biological activities (anti-inflammatory and anti-oxidant) of fractions and methanolic extract of *Philonotis hastata* (Duby Wijk & Margadant). African Journal of Traditional, Complementary and Alternative Medicine,2015:12(4):50-55.
43. Manoj GS, Murugan K. Phenolic profiles, antimicrobial and antioxidant potentiality of methanolic extract of a liverwort, *Plagiochila beddomei* Steph. Indian Journal of Natural Products and Resources,2012:3(2):173-183.
44. Onder A, Yıldız A, Cinar AS, Zengin G, Ak G, Ozenoglu H *et al*. The comparison of the phytochemical composition, antioxidant and enzyme inhibition activity of two moss species: *Plagiomnium ellipticum* (Brid.) T. Kop. and Antitrichia californica Sull., from southwest ecological region in Turkey. Natural Product Research, 2021, 1-6.
45. Bhattarai HD, Paudel B, Lee HK, Oh H, Yim JH. *In vitro* antioxidant capacities of two Benzonaphthoxanthenones: ohioensins F and G, isolated from the Antarctic moss *Polytrichastrum alpinum*. Zeitschrift für Naturforschung,2009:64(3-4):197-200.
46. Varela Z, Debèn S, Saxena DK, Aboal JR, Fernàndez JA. Levels of antioxidant compound glutathione in moss from industrial areas. Atmosphere,2018:9:284.
47. Karim FA, Suleiman M, Rahmat ASMAH, Bakar MA. Phytochemicals, antioxidant and antiproliferative properties of five moss species from Sabah, Malaysia. International Journal Pharmacy and pharmaceutical Sciences,2014:6:292-297.