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ANTIOXIDANT AND ANTIFUNGAL PROPERTIES OF MOSSES COMMON IN ARMENIA

G. H. SEMERJYAN *, I. H. SEMERJYAN **

Chair of Biochemistry, Microbiology and Biotechnology, YSU, Armenia

Nowadays, global health challenges such as the increased risk of diseases associated with oxidative stress and antibiotic resistance are issues of serious concern. Oxidative stress is considered the main cause of many modern pathological conditions, such as neurological disorders, ischemia, cancer, etc. Bryophytes synthesize a huge number of secondary metabolites that have therapeutic and nutraceutical potential. We assessed the free radical scavenging ability of the extracts using a common method, the DPPH radical scavenging assay. Three moss species showed good antioxidant activity. As the data obtained show, the lowest half-saturation values were observed in extracts of *Dicranum scoparium* – IC_{50}=21.13 $\mu g/mL$ (78.87% inhibition), in extracts of moss *Thuidium recognitum* (Hedw) Lindb IC_{50}=28.0 $\mu g/mL$ (72.0%), *Brachythecium salebrosum* – IC_{50}=43.75 $\mu g/mL$ (56.25%). Aqueous extract of moss *D. scoparium* had less effect on the growth of *Aspergillus flavus* and *Geotrichum candidum* with inhibition percentages of 50% and 60% respectively; and for the growth of *Mucor plumbeus* and *Cladosporium herbarum* 70% and 75%, respectively. The results indicate that these plants contain compounds with antifungal potential. Bryophytes are not damaged by fungi, bacteria and insect larvae, because they contain aromatic and phenolic substances, oligosaccharides, polysaccharides, sugar alcohols, amino acids, fatty acids, and aliphatic compounds that protect these organisms, so bryophytes have the potential for medical, pharmaceutical and agricultural use.

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Introduction. Plant cells synthesize several specialized metabolites that help them withstand various stresses. These metabolites have biological activity, which is very important from a medical, pharmacological, and biotechnological point of view. The study of various types of biological activities of plants is of great scientific interest since plant extracts are considered potential biopharmaceuticals [1]. Currently, there are several environmental problems associated with the use of synthetic fungicides in agriculture and medicine. Natural plant products have less negative impact on the environment and human health. Bryophytes are the closest modern relatives of the ancestors of the first plants that managed to adapt to life on land approximately 470–515 million years ago. They have long diversified into the following three different types: *Marchantiophyta* (liverworts), *Bryophyta* (mosses),

* E-mail: gaysemerjyan@ysu.am
** E-mail: isemerjyan@ysu.am

and *Anthocerotophyta* (hornworts). Bryophytes are found in almost all climate zones on all continents, where they are an important component of ecosystems. Bryophytes are small and morphologically simple, but chemically complex plants [2]. They are rarely eaten by animals, which is likely due to specific chemical constituents (ricciocarpin, sesquiterpenoid, acetylene oxylipins) that exhibit protective effects. Bryophytes are a valuable source of biologically active compounds (terpenoids, flavonoids, phenylpropanoids, bibenzyls) that have antimicrobial, antifungal, antitumor, and wound healing activity. There are exhibit high biological activity due to the content of secondary metabolites. There is evidence that bryophyte extracts can be used as antifungal agents (biopesticides); they are also bioindicators of environmental pollution. They are more effective than synthetic pesticides, fungicides, and insecticides, which are dangerous chemical compounds and have a detrimental effect on the environment [3].

As is known oxidative stress leads to cell damage. Disruption of redox balance leads to the formation of free radicals and hydrogen peroxide, which damage cells, including proteins, lipids, and DNA. As a result of oxidative stress, the signal transduction mechanism is disrupted. Although cells have antioxidant enzymes and non-enzymatic antioxidants, sometimes these compounds are not sufficient to counteract oxidative stress. In this case, exogenous antioxidants can restore cell redox homeostasis [4].

Fungal diseases or mycoses are numerous and varied. They are classified as contagious and infectious diseases. Infection occurs through the smallest spores that land on nails, hair, and skin. In addition, fungi can multiply in the soil and on the surface of food products. Mucor also white mold are widespread in the topsoil and develop on organic food residues. Some species cause diseases (mucormycosis) in humans and animals, and others are used to create antibiotics or as starter cultures are very dangerous because they disrupt the healthy microflora of the body and form mycotoxins. The mycelium is not divided by partitions and is represented by one giant multinucleate branched cell. *Clodosporium* – develops on food products, if sanitary and hygienic conditions for keeping food in the refrigerator are not observed [5]. It leads to food spoilage at 4–9, that is, when the growth of other types of mold stops or slows down. *Clodosporium* forms black stains, which penetrate deep into food. Mold, together with food products, penetrates the gastrointestinal tract, releasing toxins that cause poisoning in the form of mycotoxicosis, as well as allergic reactions. The mold *Geotrichum candidum* is part of the human microbiome, especially associated with saliva and feces. It is the causative agent of trichiasis in humans, as well as sour rot in plants, which affects citrus fruits, tomatoes, and other vegetables [6]. *Aspergillus* fungi are the most common in nature and resistant to environmental influences. They belong to the class of marsupial fungi, their natural habitat is soil, and they are aerobic [7]. They are often found on bread (if storage conditions are not met), and on the walls of dark and damp rooms, black rot is also known, a pulmonary form of aspergillosis can develop, as well as aspergillus meningitis. The body becomes susceptible to bacteria and viruses, creating favorable conditions for the development of tumors. Therefore, finding natural remedies to combat fungi is very important [8].

Some compounds of bryophytes can directly antagonize and reduce ROS [1]. For example, compounds that have phenolic groups in their structure (flavonoids, phenols) act as hydrogen donors for free radicals, stabilizing the excess electron on the aromatic ring through resonance. Other compounds such as flavanols act indirectly by chelating metal ions that can change the redox balance in cells (e.g., zinc and copper). In addition, they are involved in the activation of antioxidant responses in cells. Compounds such as polyphenols, bibenzyls, and terpenoids induce activation of the antioxidant system, leading to increased expression of antioxidant-cytoprotective proteins (e.g., glutathione-S-transferase, glutathione reductase, gamma-glutamylcysteine; NAD(P)H: quinone oxidoreductase, superoxide dismutase, catalase) provide long-term protection against oxidative stress. Violation of redox homeostasis leads to the emergence of various pathological conditions. Antibiotics have been used for decades for both therapeutic purposes and preventive purposes against human diseases, as well as in agriculture and animals. As a consequence, several strains resistant to antibiotics began to spread, and bacterial infections again became a threat. Bryophytes, rich in secondary metabolites exhibiting multiple biological activities, may be a valuable source for the development of new drugs that will help address both the prevention of diseases associated with oxidative stress and the problems of antibiotic resistance [9]. Unlike numerous medicinal plants that have antioxidant properties, it is very important to study the properties of bryophytes, the distinctive feature of which is resistance to adverse environmental conditions (drought, UV), and the effects of chemical agents, they can be used as natural antioxidants and antifungal agents [3].

The purpose of this work was to study the antioxidant and antifungal properties of mosses collected in Armenia.

Materials and Methods.

Plant Materials. The bryophytes viz *Amblystegiaceae*, *Dicranum scoparium (*Hedw) Warnist., *Brachytheciaceae*, *Brachythecium salebrosum* (Web et Mohr), *Thuidiaceae*, *Thuidium recognitum* (Hedw) Lindb, were collected from Armenia (at a height of ∼1450 *m*). The plants were deposited in the Takhtadjyan Herbarium of the Chair of Botany and Mycology, YSU (Vouchers no. 13450, 13451, 13456, respectively).

Plant material was carefully collected from the soil and washed thoroughly with distilled water to remove the adhering soil or extraneous particles of dust. For microbiological studies, green parts of mosses (without rhizoids) were used, which were washed with liquid soap and running distilled water. Mosses were dried at room temperature. After that, the mosses were placed in a flask and extracted with methanol, ethanol, acetone or water (1 *g* moss per 20 *mL* solvent). The extraction was carried out on a magnetic stirrer at 18–20°C for 48 *h*. After that, the samples were centrifuged at 1500 *rpm* for 10 *min*. The supernatants obtained were dried at 37°C. The resulting powder was dissolved in 580 μL of of dimethyl sulfoxide (DMSO).

DPPH Radical Scavenging Activity. The antioxidant activity was determined by using 2,2-diphenyl-picryl hydrazine (DPPH) radical scavenging activity (free radical method). Experimental samples contained moss extracts at concentrations of 10 $\mu g/mL$, 50 $\mu g/mL$, 100 $\mu g/mL$, 500 $\mu g/mL$ and 1000 $\mu g/mL$, respectively, and 125 μL of DPPH. Control samples contained 750 μL of ethanol and 125 *mL* of DPPH.

Catechin was used as a positive control. Samples were incubated at room temperature, and the absorption spectrum of solutions was measured by GENESYS 10S UV-VIS ("Thermo Scientific", Germany). The percentage of inhibition activity was calculated using the following equation:

$$\% \text{ Inhibition} = (Ac - As/Ac) \times 100,$$

where *Ac* is the absorbance of the control and *As* is the absorbance of the extract/standard. The free radical scavenging activity of samples was expressed as IC_{50} value, which represented the effective concentration of extract/standard required to scavenge 50% of DPPH radicals [10].

Determination of Antifungal Activity. For creation of associations strains of the studied fungi were cultivated in modified MRS broth (10 $g \cdot L^{-1}$ meat extract, 10 $g \cdot L^{-1}$ poly-peptone, 5 $g \cdot L^{-1}$ yeast extract, 20 $g \cdot L^{-1}$ glucose, 2 $g \cdot L^{-1}$ ammonium citrate, 0.2 $g \cdot L^{-1}$ $MgSO_4$, 0.05 $g \cdot L^{-1}$ $MnSO_4$, 1 $g \cdot L^{-1}$ Tween 80, 0.8% agar, sterilization at 1 *atm*, 15 *min*) at 37°C during 24 *h*.

The antifungal properties of moss extracts were determined by the method of total diffusion into agar. It should be mentioned, that all experiments were carried out using mod MRS media. Various species of molds were used as test organisms: *Mucor plumbeus*, *Geotrichum candidum* LMA GEO 317 (sir-dom.ru, Russia), *Cladosporium herbarum* (isolated from spoiled food and provided by Biopolymers interaction assemble, function and interaction of proteins laboratory (FIPL), INRA) [11], *Aspergillus flavus* (isolated from spoiled food and provided by Dr. K. Grigoryan, YSU, Armenia). Using diffusion into agar, 250 μL of each overnight cultural liquid was added to Petri dishes and covered by modified MRS agar. The suspension of fungal/mold spores (the amount was 104 per *mL*) was dropwise applied on the surface of the media after 48 *h* cultivation. The suspensions of fungal spores were prepared according to Bazukyan et al. [12]. The antifungal activity was detected in the absence of fungal/mold growth on the surface of the medium. The antifungal activity was compared with the results of the initial strains.

We investigated the effect of water extract of moss *Dicranum scoparium* (*D. scoparium*) on the life cycle of mold fungi *Mucor plumbeus*, *Geotrichium candidum*, *Cladosporum herbarum*, and *Aspergillus flavus*. The antifungal activity of the aqueous extract of moss *D. scoparium* was determined by the method of complete diffusion on agar in the Czapek-Dox medium. 100 μL (0.5–10.0 *mg*/*mL*) of moss extract was poured into Petri dishes, Czapek-Dox medium was added, then 200 μL of a suspension of spores of the tested fungi was added, where the final number of spores was 1×10^4. Fungal spores were collected in advance in physiological solution and their quantity was calculated in Goryaev's camera. Fungal growth in vitro was assessed every 24 *h* for 10 days by measuring the diameter of the radial growth of the mycelium for comparison with the control group. Then the Petri dishes were incubated at 25°C. The presence of antifungal activity becomes clear after 10 days when no fungal growth is observed on the surface of the Petri dishes. Petri dishes containing no moss extract were used as a control. To determine the percentage of inhibition, the following formula was used

$$\% \text{ Inhibition} = (\text{DCC} - \text{DCT})/\text{DCC} \times 100,$$

where DCC is control colony diameter, DCT is diameter of treatment colony [13].

***Statistical Analysis*.** Statistical analysis was done using one-way analysis of variance (ANOVA). The validity of differences between different series (n = 5) was evaluated by the Student's p-test: the value $p < 0.05$ was considered significant.

Results and Discussion. Reactive oxygen species (ROS) are a group of molecules that are formed under the influence of oxidases in mitochondria or other cellular compartments. ROS are highly reactive because they have unpaired electrons that can interact with oxidizable substrates through redox reactions. The main ROS involved in biological systems: are superoxide anion, hydroxyl radical, hydroperoxyl and peroxyl radical, nitric oxide, and other species such as hydrogen peroxide, singlet oxygen, and hypochlorous acid [4]. Balance between oxidants and antioxidants (redox balance) is necessary to maintain healthy cellular microenvironments. Oxidative stress is caused by a change in the balance between the production of ROS and the effectiveness of the antioxidant defense of cells. Cells and tissues are constantly exposed to free radicals generated as a result of metabolism or external factors, such as pollution, germs, allergens, radiation, cigarettes, food processing, etc. Some *in vivo* studies conducted in the 80s and 90s identified some health risks associated with the consumption of synthetic antioxidants [1].

From the point of view of chemical structure and biological properties, exogenous antioxidants represent a very large and diverse group, which can be divided into three subgroups: polyphenols, vitamins and derivatives, and antioxidant minerals [14]. Polyphenols – flavonoids and phenolic acids – are the most common natural antioxidants. Flavonoids can be divided into several groups: flavanols, flavanones, flavones, catechins, anthocyanins, and isoflavones. Polyphenols are usually secondary metabolites involved in protection against UV radiation and pathogens. They are found in all plant foods such as fruits, vegetables, juices, tea, and wine, and they provide color, taste, smell, and oxidative stability. Numerous epidemiological studies have suggested that polyphenols provide some protection against the development of diseases such as diabetes, infections, cancer, cardiovascular disease, asthma, and osteoporosis [3]. In the modern world, the human body is significantly exposed to external sources of free radicals. Consequently, the body's antioxidant defense system may not be sufficient to completely prevent oxidative damage. In this regard, antioxidant supplements or foods containing antioxidants can aid the body's defense system and help reduce or neutralize oxidative damage [15].

The antioxidant activity of moss extracts was assessed by the free radical method using DPPH. The DPPH assay is based on the assumption that an antioxidant serves as a hydrogen donor and thus reduces (decolorizes) DPPH free radicals (the color turns from purple to yellow). This assay is well-known as a basic, quick tool to evaluate the antioxidant activity of putative antioxidants. Thus, the antioxidant potency of a compound is relative to the loss of DPPH free radicals (DPPH scavenging) that can be quantified through a decrease in the maximum absorption of DPPH at 570 *nm*.

The data indicate that ethanol extracts of the studied mosses have antiradical activity (see Table).

The data showed, the lowest half-saturation values were observed in extracts of *D. scoparium* – IC_{50} = 21.13 $\mu g/mL$ (78.87% inhibition), in extracts of moss

B. salebrosum – IC_{50} = 43.75 *µg/mL*, *T. recognitum* – IC_{50} = 28.0 *µg/mL*. According to literature data [7], 67.1% inhibition of DPPH was observed in 50 *µg/mL* ethanol extracts of the moss *R. murale*, which is inferior to our data.

The antiradical activity of the extracts of the mosses (% inhibition of DPPH, n=5, p<0.05)

Extract concentration, *µg/mL*	% Inhibition of DPPH		
	B. salebrosum	*T. recognitum*	*D. scoparium*
1000	63.80 ± 1.4	92.30 ± 1.4	97.44 ± 1.4
500	56.70 ± 2.3	76.50 ± 2.3	80.30 ± 1.3
100	44.40 ± 0.2	53.10 ± 0.2	56.30 ± 0.2
50	41.0 ± 1.2	49.20 ± 1.2	51.0 ± 1.2
10	28.30 ± 0.4	41.70 ± 0.4	45.0 ± 0.4
IC_{50}	43.75	28.0	21.13

For survival, an increasing number of resistance phenomena are emerging, which makes the struggle for new and effective bioactive compounds more urgent, and the adverse effects of synthetic drugs on the environment and human health are also well documented.

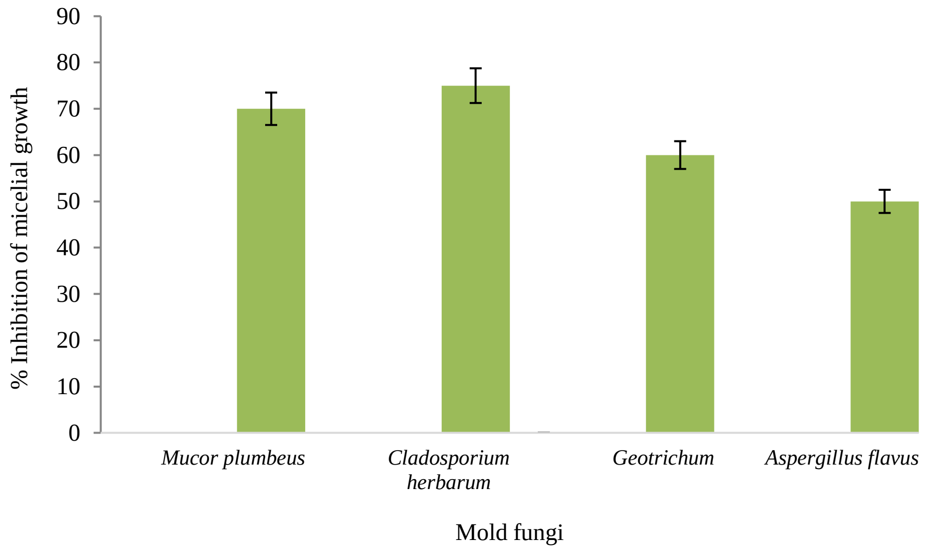
The most commonly commercialized synthetic pesticides, fungicides, and insecticides due to their indiscriminate use have increased the need to provide new natural products as alternatives to hazardous chemicals [3].

Bryophytes have an extensive chemical arsenal, numbering more than 3000 different metabolites, including terpenoids, phenolic compounds (several hundred), and other molecules such as saccharides, lipids, nitrogen- and sulfur-containing compounds. For decades, targeted research has been conducted on bryophytes in which antifungal compounds have been discovered. The fungicidal/fungistatic effect of bryophytes is highly dependent on the balsam period, as well as on seasonal, territorial (latitude, altitude, and substrate composition), and climatic changes, which specifically affect the phytochemical composition of plant tissues and, in turn, determine their pharmacological potential. As a result of the use of bioinformatics methods and non-targeted liquid chromatography moss extracts, secondary metabolites were discovered that have antimicrobial and antifungal properties, also apigenins, lunularic acid, lunularin, various marchantins, and other compounds belonging to the classes methoxyphenols, neolignans, anthocyanins, lactones which active against fungal pathogens. Antifungal agents such as derivatives of benzoic, caffeic, and coumaric acids have also been discovered [3].

Currently, there are several environmental problems associated with the use of synthetic fungicides in agriculture and medicine. Natural fungicides of plant origin have less impact on the environment and human health. Pathogenic fungi are the main infectious agents of plants, causing changes in development stages, including the post-harvest period, affecting nutritional value and limiting shelf life [12]. In some cases, mushrooms are responsible for allergic or toxic disorders among consumers due to the production of mycotoxins or allergens. Phytopathogenic fungi are typically controlled with synthetic fungicides, but their use is increasingly limited due to the harmful effects of pesticides on human health and the environment [16]. Increasing requirements for the production and regulation of agrochemicals, as well as the emergence of pathogens resistant to the products used, justify the search for new bioactive compounds and new control strategies.

Molds are widespread in the top layer of soil, they also develop on food products, also in the refrigerator, where storage rules are not followed, and in organic residues. Some species cause diseases in animals and humans, others are used to produce antibiotics or starter cultures (since some mucous membrane fungi have high enzymatic activity).

We investigated the effect of water exstract of moss *D. scoparium*, because this type of moss had high antioxidant activity.



Inhibition of mycelial growth, aqueous extract of moss *D. scoparium* (10 *μg/mL*, *n* = 5, p < 0.05).

The results (see Figure) indicate that the aqueous extract of moss *D. scoparium* can inhibit the growth of the tested mold fungi, influence the formation and growth of fungal mycelium, and prevent intensive sporulation.

The importance of plant pesticides and fungicides in particular is due to their effectiveness, biodegradability, variety of modes of action, low toxicity, and availability of starting materials.

Conclusion. This paper presents the results of a study of extracts of three mosses. Bryophytes synthesize secondary metabolites that can limit biotic stressors, are relatively unaffected by microbial diseases, and are capable of producing constitutive or inducible small molecules that have antimicrobial, antioxidant, and antifungal properties.

All extracts demonstrated antioxidant activity. Significant antioxidant activity was found in the *D. scoparium* species. Climate is the most important environmental factor that forms antioxidants in plants. Antioxidants from mosses can be used to produce new and more effective compounds that improve cellular activity and protect against oxidative stress. Based on the results, it is suggested that *D. scoparium* moss extract can be used as a readily available source of natural antioxidant for treatment.

Inhibition of the growth of colonies of mycelium of the fungi *Mucor plumbeus, Geotrichum candidum* LMA GEO 317, *Cladosporium herbarum* was observed under the influence of an aqueous extract of moss *D. scoparium*, compared to the control. Distinct morphological changes, abnormalities in the hyphae, a flaccid cell wall, and the presence of granular cytoplasm were also observed.

The results of our experiments can be used in medicine, pharmacology, and agriculture.

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Գ. Հ. ՍԵՄԵՐՋՅԱՆ, Ի. Հ. ՍԵՄԵՐՋՅԱՆ

ՀԱՅԱՍՏԱՆՈՒՄ ՏԱՐԱԾՎԱԾ ՄԱՄՈՒՌՆԵՐԻ ՀԱԿԱՕՔՍԻԴԱՆՏԱՅԻՆ ԵՎ ՀԱԿԱՍՆԿԱՅԻՆ ՀԱՏԿՈՒԹՅՈՒՆՆԵՐԸ

Այսօր գլոբալ առողջապահական խնդիրները, ինչպիսիք են օքսիդատիվ սթրեսի և հակաբիոտիկների կայունության հետ կապված հիվանդությունների ռիսկի բարձրացումը, մեծ մտահոգություն են առաջացնում: Օքսիդատիվ սթրեսը համարվում է բազմաթիվ ժամանակակից ախտաբանական պրոցեսների հիմնական պատճառը, ինչպիսիք են նյարդաբանական խանգարումները, իշեմիան, քաղցկեղը և այլն: Բրիոֆիտները սինթեզում են մեծ թվով երկրորդական մետաբոլիտներ, որոնք ունեն բուժական և սննդային ներուժ: Մենք գնահատել ենք մամուռների լուծամզվածքներիի ազատ ռադիկալների չեզոքացման ունակությունը՝ օգտագործելով ընդհանուր մեթոդը՝ DPPH ռադիկալների չեզոքացման մեթոդը: Մամուռի երեք տեսակներ ցույց են տվել լավ հակաօքսիդանտ ակտիվություն: Ինչպես ցույց են տալիս ստացված տվյալները, կիսաահագեցվածության ամենացածր արժեքները դիտվել են *D. scoparium*-ի լուծամզվածքում՝ IC_{50}=21,13 *մկգ/մլ* (արգելակում 78,87%), *T. recognitum* (Hedw) Lindb-ի լուծամզվածքում՝ IC_{50}=28,0 *մկգ/մլ* (72,0%), *B.salebrosum*-ի IC_{50}=43,75 *մկգ/մլ* (56.25%): Մամուռները հակասնկային կենսաակտիվ երկրորդային մետաբոլիտների հարուստ աղբյուր են, որոնք կարող են օգտագործվել ինչպես մարդու, այնպես էլ բույսերի պաթոգենների դեմ: *D. scoparium* մամուռի ջրային լուծամզվածքը ավելի քիչ ազդեցություն է ունեցել *Aspergillus flavus*-ի և *Geotrichum candidum*-ի աճի վրա՝ համապատասխանաբար 50% և 60% արգելակման տոկոսներով, իսկ *Mucor plumbeus*-ի և *Cladosporium herbarum*-ի աճի համար համապատասխանաբար 70% և 75%: Արդյունքները ցույց են տալիս, որ այս բույսերը պարունակում են հակասնկային ներուժ ունեցող միացություններ: Բրիոֆիտները չեն վնասվում սնկերի, բակտերիաների և միջատների թրթուրների կողմից, քանի որ կենսաբանորեն ակտիվ միացությունները, ինչպիսիք են ֆենիլխինոնը, արոմատիկ և ֆենոլային նյութերը, օլիգոսաքարիդները, պոլիսախարիդները, շաքարային սպիրտները, ամինաթթուները, ճարպաթթուները և ալիֆատիկ միացությունները պաշտպանում են այս բույսերը: Ուստի մամուռները կարող են օգնագործվել բժշկական, դեղագործական և գյուղատնտեսական ոլորտներում:

Г. Г. СЕМЕРДЖЯН, И. Г. СЕМЕРДЖЯН

АНТИОКСИДАНТНЫЕ И ПРОТИВОГРИБКОВЫЕ СВОЙСТВА МХОВ, РАСПРОСТРАНЕННЫХ В АРМЕНИИ

Сегодня глобальные проблемы здравоохранения, такие как повышенный риск заболеваний, связанных с окислительным стрессом и устойчивостью к антибиотикам, вызывают серьезную озабоченность. Окислительный стресс считается основной причиной многих современных патологических состояний, таких как неврологические расстройства, ишемия, рак и др. Мохообразные синтезируют огромное количество вторичных метаболитов, обладающих терапевтическим и нутрицевтическим потенциалом. Мы оценили способность экстрактов к улавливанию свободных радикалов, используя общий метод – анализ улавливания радикалов DPPH. Три вида мхов показали хорошую антиоксидантную активность. Как показывают полученные данные, самые низкие значения полунасыщения наблюдались у экстрактов *D. scoparium* – IC_{50}=21,13 *мкг/мл* (ингибирование 78,87%), у экстрактов мха *T. recognitum* (Hedw) Lindb IC_{50}= 28,0 *мкг/мл* (72,0%), *B. salebrosum* – IC_{50}=43,75 *мкг/мл* (56,25%). Они являются богатым источником противогрибковых биологически активных веществ, которые можно использовать против патогенов как человека, так и растений. Водный экстракт мха *D. scoparium* оказывал меньшее влияние на рост *Aspergillus flavus* и *Geotrichum candidum* с процентом ингибирования 50% и 60% соответственно; а на рост *Mucor Plumbeus* и *Cladosporium Herbarum* – 70% и 75% соответственно. Результаты показывают, что эти растения содержат соединения с противогрибковым потенциалом. Мохообразные не повреждаются грибами, бактериями и личинками насекомых, поскольку такие биологические соединения, как фенилхинон, ароматические и фенольные вещества, олигосахариды, полисахариды, сахарные спирты, аминокислоты, жирные кислоты и алифатические соединения в составе мохообразных защищают эти организмы, поэтому мохообразные имеют потенциал для медицинского, фармацевтического и сельскохозяйственного использования.