http://dergipark.org.tr/tr/pub/anatolianbryology

DOI: 10.26672/anatolianbryology.1205930

Anatolian Bryology
Anadolu Briyoloji
Dergisi
Research Article
e-ISSN:2458-8474
Online

The Biochemical Properties of Some Species of *Dicranum* Hedw.

Mustafa DEMİRBAĞ[1], Vesile YILDIRIM[2], Nevzat BATAN[3], Ökkeş YILMAZ[4], İrfan EMRE[5], Mevlüt ALATAŞ[6]*

[1] Elazığ National Education Directorate, Elazığ, TÜRKİYE,
[2,4] Fırat University, Faculty of Science, Department of Biology, Elazığ, TÜRKİYE,
[3] Karadeniz Technical University, Maçka Vocational School, Trabzon, TÜRKİYE,
[5] Fırat University, Faculty of Education, Department of Basic Education, Elazığ, TÜRKİYE,
[6] Munzur University, Tunceli Vocational School, Tunceli, TÜRKİYE.

Received: 16 November 2022 **Revised: 21 November 2022** **Accepted: 22 November 2022**

Abstract

In this study, the fatty acid compositions, lipid-soluble vitamins, sterols, flavonoids, and phenolic acid levels, as well as the DPPH radical scavenging activity of five different *Dicranum* species (*D. majus, D. fuscencens, D. polysetum, D. scoparium* and *D. tauricum*) were examined. While lipid-soluble vitamins, sterols, flavonoids, and phenolic acids were evaluated by HPLC, fatty acid compositions were assessed by gas chromatography. Based on study findings, it was determined that the examined *Dicranum* species exhibit low levels of flavonoids and lipid-soluble vitamins. However, it was seen that the species under study were high in terms of phenolic acids. Particularly, it was determined that the examined species have substantial levels of gallic acid (52.96-63.1 g/g) and vanilic acid (11.96-44.83 g/g). Cinnamic acid concentration was lowest in the examined samples. The radical scavenging capacity of the examined species was found to range from 48.92% to 86.89% in 250 µl in this study. Additionally, it was discovered that the investigated species' stigmasterol contents ranged from 35.3 to 46.05 g/g. The lowest levels of ergosterol and beta-sitosterol were discovered in *D. majus* and *D. fuscescens*. Based on the results of fatty acid composition, it was discovered that oleic acid (C18:1 n9), linoelic acid (C18:2 n6), and -linolenic acid (C18:3 n3) were the predominant unsaturated fatty acids and that palmitic acid (C16:0) and behenic acid (C22:0) was the major saturated fatty acid.
Keywords: Bryophyte, *Dicranum*, Biochemical Content.

Bazı *Dicranum* Hedw. Türlerinin Biyokimyasal Özellikleri

Öz

Bu çalışmada, beş farklı *Dicranum* türünün (*D. majus, D. fuscencens, D. polysetum, D. scoparium* ve *D. tauricum*) yağ asidi bileşimleri, yağda çözünen vitaminler, steroller, flavonoidler ve fenolik asit seviyeleri ile DPPH radikal yakalama aktiviteleri incelenmiştir. Yağda çözünen vitaminler, steroller, flavonoidler ve fenolik asitler HPLC ile değerlendirilirken, yağ asidi bileşimleri gaz kromatografisi ile değerlendirilmiştir. Çalışma bulgularına dayanarak, incelenen *Dicranum* türlerinin düşük düzeyde flavonoidler ve yağda çözünen vitaminler sergiledikleri belirlenmiştir. Fakat incelenen türlerin fenolik asitler açısından yüksek olduğu görülmüştür. Özellikle incelenen türlerin önemli düzeyde gallik asit (52,96-63,1 g/g) ve vanilik asit (11,96-44,83 g/g) içerdiği belirlenmiştir. Sinnamik asit konsantrasyonu ise incelenen örneklerde en düşüktür. Bu çalışmada incelenen türlerin radikal yakalama kapasiteleri 250 µl'de %48,92 ile %86,89 arasında değişmektedir. Ayrıca incelenen türlerin stigmasterol içeriklerinin 35,3 ile 46,05 g/g arasında değiştiği saptanmıştır. En düşük ergosterol ve beta-sitosterol seviyeleri ise *D. majus* ve *D. fuscescens*'te bulunmuştur. Yağ asidi bileşimi sonuçlarına göre; oleik asit (C18:1 n9), linoelik asit (C18:2 n6) ve -linolenik asit (C18:3 n3)'ün baskın doymamış yağ asitleri, palmitik asit (C16:0) ve behenik asit (C22:0) ise başlıca doymuş yağ asitleridir.
Anahtar kelimeler: Briyofit, *Dicranum*, Biyokimyasal İçerik.

* Corresponding author: mevlutalatas@hotmail.com

To cite this article: *Demirbağ M. Yıldırım M. Batan N. Yılmaz Ö. Emre İ. Alataş M. 2022. The Biochemical Properties of Some Species of Dicranum Hedw. Anatolian Bryology. 8:2, 140-148.*

1. Introduction

Until the recent molecular phylogeny studies, bryophytes were classically classified into three classes under the division Bryophyta. Studies on rRNA sequences and chloroplast genes with low variability besides morphological characters revealed that it would be correct to consider these three classes in 3 divisions under the subkingdom Bryobiotina. These divisions consist of Marchantiophyta (Liverworts, about 5,000 species), Anthocerotophyta (Hornworts, about 150 species), and Bryophyta (Mosses, about 13,000 species) (Glime, 2009; Goffinet and Shaw, 2009).

In this study, taxa belonging to the division Bryophyta, the class Bryopsida, the order Dicranales, the genus *Dicranum* of Dicranaceae were used. The *Dicranum*, which prefers arctic and cold climates, has about 150 species in the world and 31 of them live in Europe (Aysel and Şenkardeşler, 2002; Hodgetts and Lockhart, 2020). The number of taxa belonging to the genus *Dicranum* in our country is 16 (*D. polysetum* Sw. ex anon., *D. bonjeanii* De Not., *D. majus* Sm., *D. leioneuron* Kindb., *D. scoparium* Hedw., *D. tauricum* Sapjegin, *D. montanum* Hedw., *D. flagellare* Hedw., *D. viride* (Sull. & Lesq.) Lindb., *D. fulvum* Hook., *D. scottianum* Turner, *D. brevifolium* (Lindb.) Lindb., *D. fuscescens* Sm., *D. flexicaule* Brid., *D. muehlenbeckii* Bruch & Schirnp. and *D. spadiceum* J.E.Zetterst) (Kürschner and Frey, 2020). Studies on bryophytes in our country are generally for bryofloristic purposes and there are almost no studies on the vitamin, sterol, phenolic acid, flavonoid, or DPPH contents (Tonguç Yayıntaş et al., 2017; Çöteli et al., 2017, 2019; Aydın, 2020; Aydın et al., 2021). Based on this situation, the aim of this research is to determine some biochemical contents (fatty acid compositions, vitamin, sterol, flavonoid, and phenolic acid contents) and DPPH radical scavenging capacities of five species (*D. majus* Sm., *D. polysetum* Sw. ex anon., *D. scoparium* Hedw., *D. tauricum* Sapjegin, *D. fuscescens* Sm.) of *Dicranum*.

Chemicals called secondary metabolites, which have antimicrobial activity, play a role in the defense mechanisms of bryophytes. In the researches; Some moss species have been reported to have antimicrobial activity (Altuner et al., 2010; Öztopçu Vatan et al., 2011; Elibol et al., 2011; Savaroğlu et al., 2011a,b; Çolak et al. , 2011; Ertürk et al., 2015). Antibacterial, antifungal, antioxidant and antiviral activities of some bryophyte species are also known (Glime and Saxena, 1990; Basile et al., 1999; Elibol, 2010; Uyar et al., 2016; Çakır Sahilli and Alataş, 2021). In addition, it has been reported that there are aromatic compounds, terpenoids, and fatty acids that cause antimicrobial effects in the contents of mosses. Using the disc diffusion method, ethanol and methanol extracts of some moss species have also been found to have antimicrobial activities against *Salmonella, Escherichia coli, Pseudomonas aureginosa, Staphylococcus aureus, Bacillus cereus, Candida albicans* and *Saccharomyces cerevisiae* microorganisms (Öcalan, 2012).

2. Material and Methods

The table 1 below lists the locations of the five *Dicranum* species that were the subject of this study: *D. majus, D. polysetum, D. scoparium, D. tauricum,* and *D. fuscescens.*

Table 1. Localities of the studied *Dicranum* species

Taxa	Localities
D. majus	Ardahan (Center): Yalnızçam Forest, 41°02'43"N/42°29'00"E, 1918-2000 m, 07.09.2014
D. fuscescens	Ardahan (Center): Ardahan exit, Cemal Turan Nature Park, 41°07'23"N/42°47'05"E, 1970 m, 06.09.2014
D. polysetum	Ardahan (Center): Yalnızçam Forests, Hasköy Forests-2, 41°01'46"N/42°23'47"E, 2000-2150 m, 07.09.2014
D. scoparium	Ardahan, Hanak: Karakale village plateau, Uzundere, Çat plateau and flowery mountain plateau, 41°19'25"N/42°41'41"E, 2320-2800 m, 06.07.2014.
D. tauricum	Ardahan (Center): Between Çıldır and Ardahan, inside the Pinus forest, 41°08'13"N/42°54'00"E, 1930-2000 m, 06.09.2014

2.1 Chromatographic Analysis of Flavonoids and Phenolic Acids

The phenolic compounds were identified by Zu et al. (2006) using the procedure recommended in this work and a PREVAIL C18 reversed-phase column (15x4.6mm, 5m, USA) as the column. Flavonoid content analysis was conducted via DAD separation. The identification of flavonoids was carried out using the following wavelengths: 280 nm (catechin, naringin), 254 nm (rutin, myricetin, morin, and quercetin), 306 nm (resveratrol), and 265 nm (kaempferol). The results were expressed as

"g/g" when the chromatographic peaks of the extracts were compared to the results from the standards.

2.2 DPPH Radical Reduction Method

The radical reduction activities of *Dicranum* species were ascertained using the approach suggested by Liyana-Pathiranan and Shahidi (2005). This procedure involved making DPPH by dissolving 25 mg/l of methonal in it. Four milliliters of this solution were then taken and applied to the samples that had been dissolved in 50, 100, and 250 L of DMSO, respectively. After 30 minutes of darkness and room temperature, samples were read at 517 nm in a spectrophotometer. DPPH• Radical Sweep Percentage % = [(A0 – A1)/A0] x 100

A0: Control absorbance, A1: Sample absorbance (Kürşat et al., 2011).

2.3 Extraction of Lipids

For the extraction of lipids, Hara and Radin's 1978 technique was used. This procedure involved homogenizing one gram of plant material at 6000 rpm for ten minutes after combining it with 10 ml of hexanisopropanol (3:2, v/v). The supernatant was then divided up into various test tubes at the conclusion of this time.

2.4 Preparation of Fatty Acid Methyl Esters

The samples were first added to 5 ml of sulfuric acid diluted in 2% methanol to create methyl esters, and they were then maintained at 50°C for an average of fifteen hours. After this time, the samples were mixed to with 5 ml of 5% NaCl and 5 ml of hexane, and the top phase was then transferred to another test tube. Following these procedures, 5 ml of $KHCO_3$ was added to the samples to assure phase formation before 45°C evaporation was applied to the samples. The samples were taken into vials after being dissolved in 1 ml of hexane following the completion of all these procedures (Christie, 1990). The standards were compared to fatty acid methyl esters, and calculations were done.

2.5 Gas Chromatographic Analysis of Fatty Acid Methyl Esters

Examining fatty acids Gas chromatography was used to perform SHIMADZU GC 17 Ver. 3. When getting the results, mixtures comprising typical fatty acid methyl esters were used to define the fatty acid determination times. The injection (240°C) and detector (280°C) temperatures were also set, and the column temperature was maintained between 120 and 220°C. According to Bahşi (2008), the amount of fatty acids discovered by the study is reported as a percentage.

2.6 Vitamin and Sterol Analysis

Following one minute of centrifugation at 6000 x g at 4 °C, one gram of plant extract was combined with five milliliters of acetonitrile/methanol (75/25) for ten minutes. After completing this procedure, the superanatant was collected into 1 ml vials and prepared for use in HPLC. The absorbances of each vitamin were measured at 202 nm for sterols, 235 nm for K1, tocopherol, D2, D3, tocopherol acetate, and 215 nm for retinol and retinol, using Supelcosil TM LC18 (2504.6 mm, 5 m, Sigma, USA) as a column in the study. It was discovered that it was 220 nm for retinol acetate. The Class Vp 6.1 program was used, and the findings were expressed in terms of g/g (Bahşi, 2008; Kürşat et al., 2011).

3. Results

When the flavonoid results of *Dicranum* species are examined, it is seen that they are generally low (Table 2). However, it is seen that *D. majus* has a relatively higher content of rutin (2.5 µg/g) and catechin (5.86 µg/g). At the same time, the amount of catechin (6.33 µg/g) of *D. fusecens* was found to be higher than other species. In addition, the routine content of *D. scoparium* was found to be 1.5 µg/g.

Table 2. The flavonoid contents of studied *Dicranum* species

Taxa	Ru.	My.	Mo.	Q.	K.	C.	N.	Na.	Re.
D. majus	2.5	0.1	-	-	0.1	5.86	-	-	-
D. fuscescens	0.03	0.36	-	0.03	-	6.33	-	0.03	0.03
D. polysetum	0.3	0.03	-	0.03	-	-	0.03	0.03	-
D. scoparium	1.5	0.1	0.03	0.03	-	-	0.1	0.03	-
D. tauricum	0.03	0.66	1	0.03	-	-	0.1	-	-

Abbreviations: Rutin (Ru), Myricetin (My), Morin (Mo), Quercetin (Q), Kaempferol (K), Catechin (C), Naringin (N), Naringenin (Na), Resvearatrol (Re).

Considering the phenolic acid results (µg/g) of *Dicranum* species; In terms of vanillic acid, *D. tauricum* (44.83 µg/g) ranks first, while *D. scoparium* (21.93 µg/g) ranks second. These include *D. polysetum* (16.63 µg/g), *D. majus* (14.00 µg/g) and *D. fuscencens* (11.96 µg/g). In terms of caffeic acid, *D. tauricum* (1.76 µg/g) and *D. scoparium* (1.16 µg/g) are in the first two places. In

terms of caffeic acid, ferulic acid, rosmarinic acid, it is seen that *D. fuscencens* is significantly higher than other *Dicranum* species. It is seen that the species belonging to the other *Dicranum* (*D. majus, D. polysetum, D. scoparium, D. tauricum*) are close to each other in terms of the specified fatty acids ratios. In terms of gallic acid, it is seen that the ratios of species belonging to the *Dicranum* are higher than other aists (vanilic acid, cinnamic acid, caffeic acid, ferulic acid and rosmarinic acid). In terms of gallic acid ratio, the highest taxon is *D. polysetum*, while the lowest taxon is *D. fuscencens* (Table 3).

Table 3. The phenolic acid contents of studied *Dicranum* species

Taxa	V.	Ci.	Ca.	F.	R.	G.
D. majus	14.00	0.13	1.13	0.76	0.53	61.16
D. fuscescens	11.96	0.06	48.66	31.76	41.76	52.96
D. polysetum	16.63	-	1.53	13.6	0.06	79.16
D. scoparium	21.93	0.23	1.16	1.13	0.46	63.1
D. tauricum	44.83	0.8	1.76	3.23	0.03	60.23

Abbreviations: Vannilic acid (V), Cinnamik acid (Ci), Caffeic acid (Ca), Ferulic acid (F), Rosmarinic acid (R), Gallic acid (G).

The taxon with the highest ratio in 50 µl and 100 µl is *D. majus*, whereas the taxon with the highest ratio in 250 µl is *D. fuscencens*, according to the DPPH radical reduction method results (%) of species belonging to the *Dicranum*. Again, it is clear that *D. fuscencens* is the second taxon with the highest ratio in 50 µl and 100 µl, and *D. tauricum* is the third taxon. *D. majus* and *D. tauricum* are the second and third taxa in 250 µl with the highest ratio, respectively. *D. polysetum* and *D. scoparium* had lower ratios in 50 µl, 100 µl, and 250 µl than other *Dicranum* species (Table 4).

Table 4. The DPPH radical scavenging activities of studied *Dicranum* species

Taxa	50 µl	100 µl	250 µl
D. majus	30.35	79.05	85.22
D. fuscescens	9.5	67.15	86.96
D. polysetum	2.33	14.28	48.92
D. scoparium	3.14	4.38	52.59
D. tauricum	5.8	37.56	77.59

It can be seen that when it comes to -tocopherol ratios, *D. scoparium* comes in first and *D. tauricum* comes in second, and they are both much higher than *D. polysetum* and *D. majus*. Despite *D. majus* taking the top spot in K1 ratios, there isn't much of a difference between those ratios and those of other *Dicranum* species. *D. scoparium* comes in second, *D. polysetum* comes in third when it comes to ergosterol values. *D. tauricum* comes in first. In terms of species and ratios, the values for stigmasterol and beta-sitosterol rank similarly to those for ergosterol. With their respective ratios, *D. tauricum, D. scoparium,* and *D. polysetum* rank in the top three (Table 5.). *D. polysetum* comes in third, *D. scoparium* comes in second, and *D. tauricum* comes in top in terms of ergosterol levels. Ergosterol values rank similarly to stigmasterol and B-sitosterol values in terms of species and ratios. The top three with regard to ratios are *D. tauricum, D. scoparium*, and *D. polysetum* (Table 5.).

Table 5. The lipide-soluble vitamin and sterol contents of studied *Dicranum* species.

Taxa	R.	Ra.	K2	Rt.	D2	D3	At.	K1	E.	S.	Bs.
D. majus	-	-	-	0.2	0.2	-	0.03	0.53	3.83	35.3	0.5
D. fuscescens	-	-	-	0.13	-	0.2	-	0.23	0.2	45.16	1.16
D. polysetum	-	-	0.26	0.43	0.23	-	0.2	0.36	22.7	44.86	17.3
D. scoparium	-	-	-	0.8	2.94	0.12	4.65	0.12	30.9	40.75	33.7
D. tauricum	-	-	0.35	0.45	0.62	0.3	3.425	0.22	56.22	46.05	36.82

Abbreviations: Retinol (R), Retinol acetate (Ra), R-tocopherol (Rt), A-tocopherol (At), Ergosterol (E), Stigmasterol (S), B-sitosterol (Bs).

When comparing the fatty acid data of several *Dicranum* species, *D. tauricum* appears to be at the top in terms of various fatty acid values (8:0, 12:0, 14:0, 14:1, 15:0, 16:0, 18:0, 18:1, 20:3, 24:1). In comparison to other ratios, those having a value of 16:0 are much greater. *Dicranum tauricum* (26.44 %) and *D. fuscencens* (9.8 %) are the two taxa with the highest and lowest values, respectively. Another interesting factor is the high ratio of 22:0. *D. fuscencens* (45.24 %), *D. majus* (37.16 %), *D. scoparium* (16.56 %), *D. polysetum* (9.74 %), and *D. tauricum* (0.87 %) are the taxa with the largest amounts in this value, respectively (Table 6).

Table 6. The fatty acid compositions (µg/g) of studied *Dicranum* species.

Fatty acids / Taxa	6:00	8:0	12:0	14:0	14:1	15:0	15:1	16:0	16:1 n7	17:0	17:1	18:0	18:1 n9	18:1 n11	18:2 n6	18:3 n6	18:3 n3	20:0	20:1 n 9	20:3 n3	20:4 n6	20:5 n3	22:0	22:1 n9	22:6 n3	23:0	24:1 n9
D. majus	0.26	0.48	0.2	0.49	0.46	0.24	0.44	13.19	3.68	0.35	0.87	2.8	9.85	-	11.58	1.55	5.19	-	2.63	2.3	0.88	-	37.16	-	1.32	-	-
D. fuscescens	0.41	0.99	1.25	0.4	0.39	0.19	1.03	9.8	1.5	0.05	0.35	3.68	6.05		7.64	1.51	8.39	1.62	2.29	3.07	1.22	0.5	45.24		1.25	-	0.15
D. polysetum	0.49	-	0.66	0.87	0.56	-	0.52	22.18	6.27	-	2.2	4.95	8.56	-	11.20	2.95	2.35	-	1.75	2.23	-	-	9.74	5.43	3.1	-	1.57
D. scoparium	0.34	0.2	2.04	0.97	1.08	0.25	0.33	16.54	5.66	1.4	1.68	3.1	3.62	1.22	6.9	1.74	3.49	-	3.96	3.23	1.24	-	16.56	1.16	6.31	-	0.79
D. tauricum	0.22	1.44	1.56	5.9	1.92	1.15	-	26.44	3.84	0.8	1.19	6.76	14.67		2.7	1.62	1.38	-	3.15	12.18	-	-	0.87	4.07	2.98	0.68	2.62

4. Discussion and Conclusion

Since bryophytes are morphologically very small, difficult to collect in big quantities, and difficult to diagnose under the microscope, their phytochemical contents have not been researched for a long time (Asakawa et al., 2013). In addition, bryophytes have been acknowledged as having little nutritional significance, and it has been shown that when individuals review older material, they do not consider them to be nutrients. However, bryophytes, particularly in China, have been utilized to treat a variety of illnesses like snakebites, TB, and external wounds (Garnier et al., 1969; Suire, 1975; Ding, 1982; Ando and Matsuo, 1984; Asakawa, 1999). But new research has revealed that bryophytes contain a significant number of biologically active compounds (Klavina, 2015). According to the bryophyte species, the extracts from bryophytes have antioxidant action and include considerable amounts of polyphenolic chemicals (Singh et al., 2006; Cheng et al., 2012; Fu et al., 2012; Asakawa et al., 2013). especially bryophytes; It is underlined that it has cytotoxic activities against cancer cells as well as antifungal, antiviral, antibacterial, and neuroprotective characteristics (Spjut et al., 1986; Cheng et al., 2012). According to reports, bryophytes include flavonoids as well as alkanes, triterpenes, and highly unsaturated fatty acids (Asakawa, 1982; Asakawa et al., 2013). According to Chandra et al. (2016), lipids, proteins, organic acids, and fatty acids are only a few of the bioactive components found in bryophytes. The presence of terpenoids, steroids, polyphenols, aliphatic chemicals, lipids, proteins, organic acids, and fatty acids has been claimed to be present in bryophytes (Chandra et al., 2016).

In this study, five different species of the *Dicranum*, *D. majus*, *D. fuscencens*, *D. polysetum*, *D. scoparium* and *D. tauricum* were examined for their flavonoid and phenolic acid compounds, flavonoid and phenolic acid compounds, radical and phenolic acid capacities, and radical and fat reduction in order to help determine the phytochemical content of bryophytes in the an analysis of acid compositions was done. The saturated fatty acid composition of five *Dicranum* species was examined in this study, and it was found that they contain Margaric acid (C17:0), Stearic acid (C18:0), and Behenic acid (C22:0) in addition to Caproic acid (C6:0), Caprylic acid (C8:0), Lauric acid (C6:0), Myristic acid (C14:0), and Palmitic acid (C16:0). The five *Dicranum* species that were investigated have palmitic acid (C16:0) as the predominant saturated fatty acid (9.8-26.44%). Stearic acid is noticeable (2.8-6.76%) as the second unsaturated fatty acid. *D. tauricum* was found to be the species among the five *Dicranum* species with the highest concentration of fatty acids, mostly unsaturated ones (palmitic acid and stearic acid). For the five species examined, the unsaturated fatty acids oleic acid (C18:1 n9), linoleic acid (C18:2 n6), -linolenic acid (C18:3 n6), -linolenic acid (C18:3 n3), gondoic acid (C20:1 n9), docohexanoic acid (C22:6 n3), and ner Oleic acid (C18:1 n9) content is represented by *D. taruicum* (14.67%), linoleic acid (C18:2 n6) content by *D. majus* (11.58%), and *D. polysetum* (11.20%). *D. fuscescens* had a higher concentration of -linolenic acid (C18:3 n3) than the other two plants (8.39%). Xian'en et al. (2006) showed that *D. caesium* contains large concentrations of the fatty acids dodecanoic acid, tetradecanoic acid, hexadecanoic acid, and octadecanoic acid. According to Xian'en et al. (2006), the fatty acid content of bryophytes can play a significant role in industrial food production and food studies. In their study from 1994, Dembitsky and Rezenka discovered that bryophytes contain 86 fatty acids, of which 27 are saturated fatty acids. The researchers also discovered that these fatty acids include monoenoic acid, dienoic acid, trienoic acid, and tetraenoic acids (Dembitsky and Rezenka, 1994). Alkanes, triterpenes, and highly unsaturated fatty acids have all been identified in bryophytes (Asakawa, 1982; Asakawa et al., 2013).

The examined species do not exhibit high levels of lipid-soluble vitamin content, as can be seen (Table 5). All five of the investigated species either don't contain any lipid-soluble vitamin content at all or have very little of it. Additionally, it was found that the species were richer in stigmasterol (35.3-46.05 g/g) when the sterol contents were investigated. *Dicranum majus* (3.83 g/g; 0.5 g/g) and *D. fuscencens* (0.2 g/g; 1.16 g/g) are found to have lower levels of ergosterol and -sitosterol, respectively. The highest concentrations of ergosterol (56.22 g/g) and beta-sitosterol (36.82 g/g) were found in *D. tauricum*. Chiu et al. (1985) studied the primary sterols-dihydrobrassicasterol, sitosterol, stigmasterol, and clionasterol-found in bryophytes. In a different study, researchers discovered that bryophytes produce considerable levels of vitamins E and K as well as squalene, plastoquinone, and plastohydroquinone (Asakawa and Ludwiczuk, 1981).

Low levels of flavonoid content were discovered in the investigation (Table 2). *D. fuscescens* and *D. majus* both have relatively low routine (2.5 g/g) and catechin (5.86 g/g) contents, as well as catechin (6.33 g/g) contents. Examining the phenolic acid findings reveals that the species are particularly rich in vanillic acid (11.9-44.83 g/g) and gallic acid (52.96-79.16 g/g). *D. fuscescens* contains

significant amounts of gallic acid (52.96 g/g), rosmarinic acid (41.76 g/g), caffeic acid (48.66 g/g), and ferulic acid (31.76 g/g). seen. It can be shown that *Dicranum polysetum* has high levels of gallic acid (13.6 g/g) and ferulic acid. Cinnamic acid levels in the examined species were found to be either nonexistent or extremely low. According to reports, bryophytes include aromatic chemicals such bibenzyl, benzoate, and cinnamate, as well as bioflavonoids, terpenes, terpenoids, and flavonoids (Asakawa, 2007; Mishra et al., 2014). According to Klavina's (2015) research, bryophytes have a strong antioxidant potential and contain significant amounts of polyphenolic chemicals. Although research on phylogeny and metabolism place a lot of emphasis on flavonoids, it is well known that there are very few studies on the metabolites of bryophytes, particularly on flavonoid compounds (Wang et al., 2017). In 2017, Wang et al. conducted one of the first significant investigations on the flavonoid content of bryophytes, which makes their study significant. The amount of total flavonoid in the 90 samples that were examined ranged from 1.8 to 22.3 mg/g, according to the researchers. Additionally, researchers discovered that bryophytes cultivated at lower elevations have more flavonoids than those grown at higher elevations (Wang et al., 2017). At the same time, it was discovered that comparatively ancient bryophytes contained higher flavonoids when the findings of this study were assessed in terms of the association between total flavonoid levels and plant phylogeny (Wang et al., 2017). According to a study of Ertürk et al. (2015), hydroxyflavonoids, dihydroflavonol polycyclic aromatic hydrocarbons, hypogenols, and bioflavonoids are all found in bryophytes.

The 250 µl outcomes of this investigation (48.92-86.96%) are high when the DPPH radical reduction data are reviewed. Except for *D. majus* (30.35%), the values of the DPPH radical findings with 50 µl of the study were determined to be low. It can be observed from the analysis of the DPPH radical reduction results for 100 µl that the values for *D. scoparium* (4.38%) and *D. polysetum* (14.28%) are low. *D. majus* got the highest results for all three concentrations among the examined species. Some bryophyte species examined in a different study by Chobot et al. (2008) demonstrated radical reduction abilities and antioxidant capacity activities, although it was noted that there was no significant relationship between this condition and total phenolic content.

The Note: This study is based on the first author's thesis, "Biochemical properties of several species of *Dicranum* Hedw. (Bryoophyta)".

References

Altuner E.M. Çetin B. Çökmüş C. 2010. Antimicrobial Activity of Extracts of *Tortella tortulosa* (Hedw.) Limpr. Kastamonu University Journal of Forestry Faculty. 10: 111-116.

Ando H. Matsuo A. 1984. Applied Bryology, In: Schultze-Motel, W. (Ed.). Advancesin Bryology. 2: 133-224.

Asakawa Y. 2007. Biologically active compounds from bryophytes. Pure Applied Chemistry. 79: 557-580.

Asakawa Y. 1982. ChemicalConstituents of the Hepaticae, In: Herz, W., Grisebach, H., Kirby, G.W. (Eds.), Progress in theChemistry of Organic Natural Products. Springer. Vienna.

Asakawa Y. 1999. Phytochemistry of Bryophytes: Biologically Active Terpenoids and Aromatic Compounds from Liverworts. In: Romeo, J. (Ed.), Phytochemicals in Human Health Protection, Nutrition, and Plant Defense. Kluwer Academic/Plenum Publishers. New York.

Asakawa Y. Ludwiczuk A. 1981. Chemical Constituents of Bryophytes: Structures and Biological Activity. J. Nat. Prod., 3: 641-660.

Asakawa Y. Ludwiczuk A. Nagashima F. 2013. Chemical constituents of bryophytes: bio and chemical diversity, biological activity, and chemosystematics (Progress in the chemistry of organic natural products). Springer. Vien.

Aydın S. 2020. The free radical scavenging activities of biochemical compounds of *Dicranum scoparium* and *Porella platyphylla*. Anatolian Bryology. 6:1, 19-26.

Aydın S. Alataş M. Batan N. 2021. Fatty Acid Content and Free Radical Scavenging (Dpph) Activities of Some of Bryophytes Extracts. Fresenius Environmental Bulletin. 30:3, 2943-2951.

Aysel V. Şenkardeşler A. 2002. Systematics of Non-Seeded Plants, Volume III, Mosses (Bryophyta). ÇOMU Faculty of Arts and Sciences Publications. Çanakkale.

Bahşi M. 2008. The Effect of Reseveratrol and α-lipoic Acid on Some Biochemical Parameters in Tissues and Serums of 7,12 DMBA Treated Elderly Rats. Fırat University, Institute of Science.

Basile A. Giardano S. Lopez-Sa'ez J.A. Cobianchini C.R. 1999. Antibacteria lactivity of pure flavonoids isolated from mosses. Phytochemistry. 52, 1479-1482.

Chandra S. Chandra D. Barh A. Bhatt P. Pandey K.R. Sharma I.P. 2016. Bryophytes: Hoard

of remedies, an ethno-medicinal review. Journal of Traditional and Complementary Medicine. 7, 1-5.

Cheng X. Xiao Y. Wang X. Wang P. Li H. Yan H. Liu Q. 2012. Anti-tumor And proapoptic activity of ethanolic extract and its various fractions from *Polytrichum commune* L. Ex Hedw in L1210 cells. Journal of Ethnopharmacology. 143: 49-56.

Christie W.W. 1990. Gas Chromatography and lipids. The oily press. Glaskow.

Chobot V. Kubicova L. Nabbout S. Jahoda´rˇ. Hadacek F. 2008. Evaluation of Antioxidant Activity of Some Common Mosses. Verlag der Zeitschrift für Naturforschung. Tübingen.

Çakır Sahilli Y. Alataş M. 2021. Investigation of the antioxidant properties of *Pterigynandrum filiforme* Hedw. International Journal of Biosciences. 19:5, 42-47.

Çolak E. Kara R. Ezer T. Yuvalı Çelik G. Elibol B. 2011. Investigation of antimicrobialactivity of some Turkish pleurocarpic mosses. African Journal of Biotechnology. 10: 12905-12908.

Çöteli E. Alataş M. Batan N. 2017. Comparing of GlutathioneIngredients of *Syntrichia ruralis* and *Syntrichia montana* (Pottiaceae) Taxa. AnatolianBryology. 3: 25-30.

Çöteli E. Alataş M. Batan N. Hazer Y. 2017. Comparing of Glutathione Ingredients of Some Species in Bryaceae Family. Anatolian Bryology. 5: 15-21.

Dembitsky V.M. Rezenka T. 1994. Acetylenic fatty acids of the Dicranaceae. Phytochemistry. 36, 685-689.

Ding H. 1982. Zhongguo Yao Yun Baozi Zhi Wu. KexueJishu Chuban She. Shanghai.

Elibol B. Ezer T. Kara R. Celik G.Y. Colak E. 2011. Antifungal and antibacterial effects of some acrocarpic mosses. African Journal of Biotechnology. 10: 986-989.

Elibol B. 2010. Determination of Antifungal and Antibacterial Effects of Some Acrocarpic Mosses. Ömer Halisdemir University, Institute of Science.

Ertürk Ö. Şahin H. Y. Ertürk E. Hotaman H.E. Koz B. Özdemir Ö. 2016. The antimicrobial and antioxidant activities of extracts obtained from some moss species in Turkey. Herbapolonica. 61: 52-65.

Ertürk Ö. Şahin H. Ertürk E.Y. Hotaman H.E. Koz B. Özdemir Ö. 2015. The antimicrobial and antioxidant activities of extract obtained from some mosss species in Turkey. From Botanical to Medical Research. 61: 52-65.

Fu P. Lin S. Shan L. Lu M. Shen Y.H. Tang J. Liu R.H. Zhang X. Zhu R.L. Zhang W.D. 2012. Constituents of themoss Polytrichum Commune. Journal of Natural Products. 72: 1335-1337.

Garnier G. Bezaniger-Beauquesne L. Debraux G. 1969. Ressources médicinales de la florefrancaise. Vigot Frères Éditeurs. 1: 78-81.

Glime J.M. Saxena D.K. 1990. Uses of Bryophytes Today and Tomorrow. Printers and Publishers. New Delhi.

Goffinet B. Shaw A.J. 2009. Bryophyte Biology. Cambridge University Press. Cambridge.

Hodgetts, N. & Lockhart, N. 2020. Checklist and country status of European bryophytes update 2020. *Irish Wildlife Manuals*, No. 123. National Parks and Wildlife Service, Department of Culture, Heritage and the Gaeltacht, Ireland.

Hara A. Radin N.S. 1978. Lipid extraction of tissues with a low-toxicity solvent. Anal. Biochem. 90: 420-426.

Klavina L. 2015. A study on bryophyte chemical composition-search for new Applications. Agronomy Research. 13, 969-978.

Kürşat M. Emre İ. Yılmaz Ö. Erecevit P. 2011. Antioxidant and Antimicrobial Activity in the Seeds of *Origanum vulgare* L. subsp. *gracile* (C. Koch) Letswaart and *Origanum acutidens* (Hand.-Mazz.) Letswaart from Turkey. Grasasy Aceites. 62: 410-417.

Kürschner H. Frey W. 2020. Liverworts, mosses and hornworts of Southwest Asia (Marchantiophyta, Anthoceratophyta, Bryophyta). Nova Hedwigia. 149: 1-267.

Liyana-Pathiranan C.M. Shahidi F. 2005. Antioxidant activity of commercial soft and hard wheat (*Triticum aestivum* L.) as affected by gastric pH conditions. J. Agric. Food Chem. 53: 3-2440.

Mishra R. Pandey V.K. Chandra R. 2014. Potential of Bryophytes As Therapeutics. International Journal of Pharmaceutıcal Sciences and Research. 5: 3584-3593.

Öztopçu Vatan P. Savaroğlu F. Filik İşcen C. Kabadere S. İlhan S. Uyar R. 2011. Antimicrobial and Antiproliferative Activities of *Homalothecium sericeum* (Hedw.) Schimp. Extracts. Fresenius Environmental Bulletin. 20: 461-466.

Öcalan N. 2012. Antimicrobial Activity of Mosses. Erciyes University. Health Sciences Institute.

Savaroğlu F. Filik İşcen C. İlhan S. 2011a. An Evaluation of theAntimicrobial Activity of Some Turkish Mosses. Journal of MedicinalPlants. 5: 3286-3292.

Savaroğlu F. Filik İşcen C. Öztopçu Vatan P. Kabadere S. İlhan S Uyar R. 2011b.

Determination of Antimicrobial And Antiproliferative Activities of the Aquatic Moss *Fontinalis antipyretica* Hedw. Turkish Journal of Biology. 35: 361-369.

Singh M. Govindarajan R. Nath V. Rawat A.K.S. Mehrotra S. 2006. Antimicrobial, wound healing and antioxidant activity of *Plagiochasma appendiculatum* Lehm. Et Lind. Journal of Ethnopharmacology. 107: 67-72.

Spjut R.W. Suffness M. Cragg G.M. Norris D.H. 1986. Mosses, liverworts and hornworts screened for antitumor agents. Economic Botany. 40: 310-338.

Suire C. 1975. Chimiedesbryophytes. Rev. Bryol. etLichenol. 41: 105-256.

Tonguç Yayıntaş Ö. Sögüt Ö. Konyalıoğlu S. Yılmaz S. Tepeli B. 2017. Antioxidant Activities and Chemical Compositon of Different Extracts of Mosses Gathered FromTurkey. AgroLifeScientific Journal. 6: 205-213.

Uyar G. Hacıoğlu Doğru N. Ören M. Çavuş A. 2016. Determining Antibacterial Activity of Some Mosses (Cinclidotusriparius Hostex Brid.) Arn., *Calliergonella cuspidata* (Hedw.) Loeske, *Thamnobryum alopecurum* (Hedw.) Gangulee, *Leucobryum juniperoideum* (Brid.) Müll. Hal., *Cirriphyllum crassinervium* (Taylor) Loeske & M.Fleisch.). Anatolian Bryology. 2: 1-8.

Wang X. Cao J. Dai X. Xiao J. Wu Y. Wang Q. 2017. Total flavonoid concentrations of bryophytes from Tianmu Mountain, Zhejiang Province (China): Phylogeny and ecological factors. PLoS One. 12, e0173003, doi:10.1371/journal.

Xian'en Z. Honglun W. Chenxu D. Yourui S. Jing S. Guichen C. Xuejun S. Jinmao Y. 2006. Determination of Free Fatty Acids from Soil and Bryophyteby HPLC with Fluorescence Detection and Identification with Mass Spectrometry. Chinese Journal of Analytical Chemistry. 34: 150-155.

Zu Y.G. Li C.Y. Fu Y.J. Zhao C.J. 2006. Simultaneous Determination of Catechin, Rutin, Quercetin Kaempferol and Isorhamnetin in the Extract of Sea Buckthorn (*Hippophae rhamnoides* L.) leaves by RP-HPLC with DAD. J. Pharmaceutical and Biomedical Analysis. 41: 714-719.