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*Review Article*

# Overview of bryophyte flora research in Serbia with presentation of the Serbian BRYO database

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**ABSTRACT:** Bryophyte flora research in Serbia was rather sporadic until the end of the 19th century, when a group of mostly high-school teachers started researching bryophytes. This was the first fruitful period of exploration, with many new country records. Thereafter, not many researchers investigated bryophytes in Serbia, and the majority of chorological data came from vegetation, ecological, or palaeobotanical studies. This lasted until the 1990s, when a revival of bryophyte investigation occurred, bringing with it many floristic studies and new species records for the country. At the present time, Serbia is considered to be rich in bryophyte diversity, with as many as 797 species. However, further study and a critical approach to the bryophyte flora of Serbia are needed.

**Keywords**: mosses, liverworts, state of knowledge, history, the Balkans, bryology

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## INTRODUCTION

Serbia is situated in the central part of the Balkan Peninsula, which is one of the floristically richest areas of Europe, a so-called European centre of diversity (Stevanović 2005). However, until the end of the last century, knowledge about the distribution of most of the bryophyte taxa in Serbia was scattered and/or incomplete. While some regions of the country were explored repeatedly by many authors [the Vlasina region (Matouschek 1899; Jurišić 1900; Košanin 1910; Papp *et al.* 2012), Mt. Golija (Košanin 1909; Gajić 1989; Papp & Erzberger 2005), Mt. Kopaonik (Katić 1906; Mišić & Popović 1960; Papp *et al.* 2004)], others were poorly studied or not even investigated at all. Recently, exploration of the bryological flora has been revived and intensified. The results of many new field investigations and revision of the available historical Serbian bryophyte collections have resulted in many new records for the country, as well as more detailed knowledge about the species diversity of bryophytes and their distribution and ecology in Serbia. In light of the recent intensified development of bryology in Serbia, the purpose of the present study was to give a complete overview of bryophyte exploration in Serbia.

## MATERIAL AND METHODS

Review of historical collections and perusal of available literature took a main part in forming the scientific basis for continuation of research on the bryophyte flora of Serbia, making it possible to take a critical approach to Serbian bryophytes. The data were unified into a database named BRYO, and the present analyses relied on 26471 records deposited in the subsequently updated database, which follows contemporary nomenclature according to Ros *et al.* (2007) for liverworts and Ros *et al.* (2013) for mosses. This has made it possible to plan the investigation of under-recorded species and bryologically un-investigated areas of Serbia. It will be the basis for a new inventory of the Serbian bryophyte flora, which can then serve as the main source for writing new editions of "The Bryophyte Flora of Serbia" and conducting further targeted research.

Bryological research in Serbia can be divided into three periods: early (from 1843 to 1920), middle (from

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1921 to 1990), and modern (from 1991 to the present day).

## RESULTS

***Early period.*** The early period started with the first published record and lasted until the early 20th century.

The first publication to include a bryophyte record for the territory of Serbia was the one produced by Grisebach (1843). In his paper *Spicilegium Florae rumelicae et bithynicae exhibens synopsis plantarum*, he cited *Madotheca navicularis* NE. (syn. *Porella platyphylla* (L.) Pfeiff.) growing on limestone rock by the Danube. After him, Pančić collected bryophyte material during his field trips, but he published only 12 bryophyte records, from sandy and serpentine habitats (Pančić 1859, 1863). More intensified and detailed bryophyte research was begun at the end of 19th century, with the field work of a group of high-school teachers (Spira Dimitrijević, Đura Ilić, Živojin Jurišić, Danilo Katić, and Miloje Simić), as well as that of the geographer Jovan Cvijić and the geobotanist Lujo Adamović. Most of the collected material from that period was published by Jurišić (1900), and subsequently by Katić (1900, 1903, 1906, 1907a,b, 1909) and Simić (1892, 1897, 1898, 1900). Part of this collection was published mainly by Austrian bryologists to whom they sent unidentified material, namely Franz Matouschek (Matouschek 1899, 1901) and Richard Wettstein (Wettstein 1890). After them, Nedeljko Košanin explored bryophytes of Mt. Golija (Košanin 1908, 1909) and the Vlasina plateau (Košanin 1910). This period can be regarded as a small but significant step forward in exploration of the bryophyte flora of Serbia, but it was unfortunately stopped by World War I.

***Middle period.*** The Middle period can be treated as that which started after the First World War with the work of researchers Josef Podpera from Brno and Alfred Pichler from Zagreb.

Podpera published accounts of specimens collected during his field trips to the environs of Niš, the Vlasina plateau, and the vicinity of Vranje (Podpera 1922). After him, Pichler mentioned a few wetland species (Pichler 1931) collected by Nedeljko Košanin and Teodor Soška. He later published a contribution reporting bryophytes growing on rotten wood (Pichler 1939) and tree bark (Pichler 1940). During his botanical work, Teodor Soška also explored bryophytes growing next to vascular plants. He gathered his own data and examined herbarium specimens collected by Pančić, Jurišić, and other investigators. In addition to this, Soška published a paper on bryophtes of the wider Belgrade area (Soška 1949). In this work, he also included material collected on Mt. Fruška Gora, on Mt. Kosmaj, in the Deliblato sands, in Vršac, and at a few other localities. Pavle Černjavski also collected bryophyte material, but he published reports of only a few species from Lake Blace (Černjavski 1932) and the Vlasina plateau (Černjavski 1938). Moreover, he was the first to give keys for identification of 50 species of bryophytes (nine liverworts and 41 mosses) from the environs of Belgrade (Černjavski 1937). In the meantime, with the development of vegetation sciences, bryophytes started to became an important part of relevees in vegetation studies. Thus, Ivo Horvat mentioned two mosses from the Šar Planina Mountains (Horvat 1935), Oleg Grebenščikov a couple of mosses from Žljeb (Grebenščikov 1943), Rüdiger Knapp several more from Bukovo near Negotin (Knapp 1944), and Igor Andejevič Rudski a few mosses from Mt. Ošljak (Rudski 1936), as well as 31 species from deciduous forests of Šumadija (Rudski 1949). Further on, up until the late 1980s, the majority of bryophyte records from this period were obtained from phytocoenological tables published by various authors (e.g., Jovanović-Dunjić 1952; Mišić & Popović 1960; Gajić 1961; Janković & Bogojević 1976; Jovanović 1977; Janković 1982; Jovanović *et al.* 1983; Gajić 1989; Mišić & Panić 1989).

In 1955, Zlatko Pavletić (Pavletić 1955) published the most comprehensive work on distribution of the bryophytes not only of Serbia, but also of Yugoslavia. In his *Bryophyte Prodromus of Yugoslavia*, he compiled all known chorological data on bryophytes. For the territory of Serbia, he listed 57 liverworts and 317 mosses, 374 bryophyte species altogether. He also published the first bryophyte flora of this region (Pavletić 1968). In his *Flora of Yugoslavian Bryophytes,* he gave identification keys, descriptions, and illustrations for 913 taxa occurring in Yugoslavia. The period after Pavletić was followed by a huge decrease in field bryology. Pavletić himself could not do much field work due to the fact of his being an invalid, and other investigators summarised citations or records of other authors rather than carrying out new and targeted research. Up until the beginning of the 21st century, not many strictly bryological reports were published during this period.

Andrej Martinčič, a plant ecologist from Ljubljana, also collected bryophytes at that time and was mostly occupied with exploring and collecting alpine bryophytes of Yugoslavia. He listed all moss species, both from the literature and from herbariums of Ljubljana University's Department of Biology and the Ljubljana Museum of Natural History, as well as those from his own personal collection, in *Catalogus Florae Jugoslavie* (Martinčič 1968). He also made an important contribution to knowledge of the bryophyte flora of the Šar Planina and Prokletije Mountains (Martinčič 1963, 1980), although he didn't publish part of the material collected from the Prokletije Mountains until recent times (Martinčič 2006). Mića Popović investigated the bryophyte flora of protected areas of Serbia (Popović 1966), listing a total of 25 liverwort and 148 moss species from 13 sites across

Serbia. Further, János Guelmino explored the cryptogam flora of saline areas in Vojvodina (Guelmino 1970, 1972, 1973), and Petar Grgić investigated bryophytes growing in habitats with *Picea omorika* (Pančić) Purk. in the Mileševka canyon (Grgić 1983). Several authors were engaged in exploring various aspects of mires in Serbia, contributing in their research to knowledge about the distribution of bryophytes of mire habitats. Thus, while studying the history of peat-bogs, Gigov & Nikolić (1954) mentioned six mosses and one liverwort growing on Mt. Ostrozub, and four mosses growing in the Stara Planina Mountains (Gigov 1956). While exploring the insectivorous vascular flora, Čolić (1965) mentioned an additional eight mosses (five of which were *Sphagnum* species) growing in peat-bogs of the Stara Planina Mountains. Čolić & Gigov (1958) noted 18 bryophyte species for the Crveni potok peat-bog (Mt. Tara). Finally, Tešić *et al.* (1979) presented a detailed overview of the distribution of all mires in Serbia, giving data on the distribution of a few moss species.

***Modern period.*** The modern (contemporary or current) period started with somewhat intensified exploration of the bryophyte flora in the decades after the year 1991.

Gajić *et al.* (1991) summarised species known to occur in Serbia, citing 60 liverworts and 355 mosses, 415 species altogether; this number represents 41 more than stated in Pavletić (1955). At that time, several authors started working on the bryophyte flora, and since then bryological research has so to say flourished. In order to ascertain changes in species composition, authors explored not only many historical sites, but also places that have only a few species records or have never been bryologically investigated before. Marko Sabovljević, himself or with collaborators, started to work on bryophytes at the end of 1990s, exploring the bryophyte floras of the Šar Planina Mountains (Sabovljević 1998); parts of Banat, Bačka, and Srem (Sabovljević 2003a, b); Mt. Avala (Sabovljević & Cvetić 2003); Fruška Gora (Cvetić & Sabovljević 2005); Đerdap National Park (Sabovljević 2006); and Mt. Boranja (Pantović & Sabovljević 2013). Fruitful collaboration with the Hungarian bryologist Beata Papp from Budapest and her colleagues resulted in the finding of many species new for the bryophyte flora of Serbia. Also, many regions have been bryologically investigated in greater detail, which has yielded valuable information about many potentially interesting conservation sites or simply bryologically important areas of Serbia: the Petnica region (Papp & Sabovljević 2001); Tara National Park (Papp & Sabovljević 2002); Mt. Kopaonik (Papp *et al.* 2004); the Golija-Studenica Biosphere Reserve (Papp & Erzberger 2005); Đerdap National Park (Papp *et al.* 2006); the Stara Planina Mountains (Papp & Erzberger 2007); the Suva Planina Mountains (Papp & Erzberger 2009); the Vršac Mountains (Papp & Sabovljević 2010); the region of Lake Vlasina (Papp *et al.* 2012); the Pešter plateau (Papp *et al.* 2014); and the Ibar valley (Papp *et al.* 2016a). Marko Sabovljević has started important work on preparing a major work treating the bryophyte flora of Serbia, which is of great importance in view of the fact that no comprehensive identification key for all species occurring in Serbia is currently available in the Serbian language. The first volume of this series - *The Bryophyte Flora of Serbia. I. Peat-mosses (Sphagnophyta)* (Sabovljević 2015) - has been published to date.

Milan Veljić (Belgrade) also noticed a large gap in bryophyte knowledge and published records of bryophytes from four well-springs of the Dinaric Alps and Carpathian karst (Veljić *et al.* 1996). In further work, he explored the bryophyte flora of the Grza and Crni Timok rivers, the Uvac gorge, Mt. Zlatar, and the Đavolja Varoš natural monument (Petković *et al.* 2000; Veljić *et al.* 2001; Veljić *et al.* 2006; Veljić *et al.* 2008).

Similarly, Svetlana Grdović (Belgrade) published an important contribution to knowledge about the current state of the bryoflora in the of wider area of Belgrade (Grdović & Stavretović 2004; Grdović 2005; Grdović & Stevanović 2006; Sabovljević & Grdović 2009) and the Zasavica special nature reserve (Grdović & Blaženčić 2001).

Finally, we note that interest in bryology is increasing in Serbia. At the University of Novi Sad, our young colleague Miloš Ilić entered the field of bryophyte flora research with a small contribution to knowledge of the bryophyte flora of Mt. Vidlič (Ilić *et al.* 2015).

In the course of exploration of its bryophyte flora, numerous species new for the country have been discovered during the modern period, as can be seen in the many papers containing new country records that have been published during this period (e. g., Veljić & Marin 1997; Sabovljević 1999; Pócs *et al.* 2004; Erzberger & Papp 2007; Sabovljević *et al.* 2010; Ellis *et al.* 2011a, 2011b, 2012a, 2012b, 2014, 2015; Papp *et al.* 2012, 2013, 2014a, 2014b, 2016b; Pantović *et al.* 2014). During the modern period, a total of 85 references treating the bryophyte flora have been published to date.

**Herbarium collections.** According to Pavletić (1955), specimens collected by the first researchers from the beginning of exploration to the middle of the 20$^{th}$ century are kept in the herbarium of the Natural History Museum in Belgrade (BEO), part of which was destroyed during the war. However, this collection was forgotten and remained neglected with unnamed specimens for a long time. Sabovljević and collaborators started work on revision of the material in BEO, and they have already found some interesting and valuable specimens. For example, from that collection they published records of two species new for the flora of Serbia that were collected in the first half of 20$^{th}$ century by Glišić, Černjavski, and even Lindtner

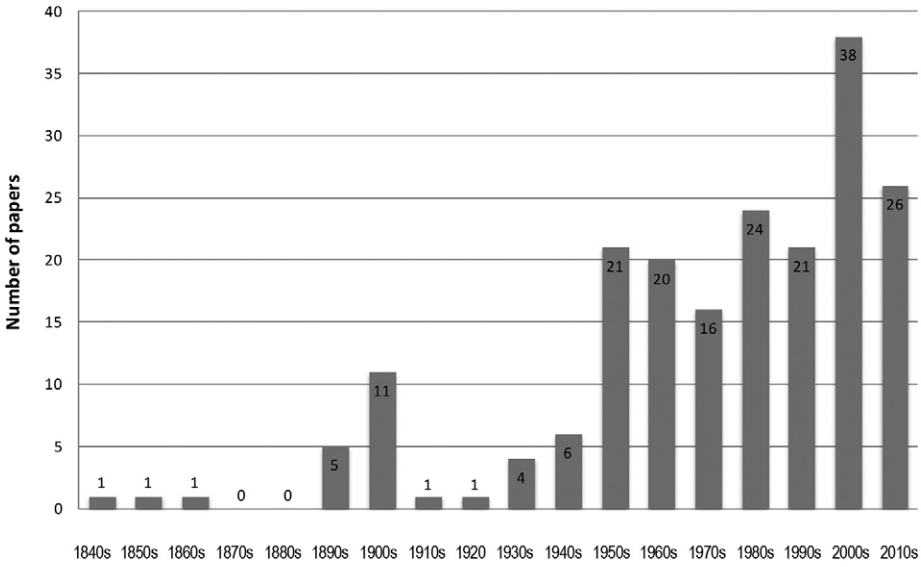


**Fig. 1.** Number of papers with records of bryophytes in Serbia (by decades).

(Pantović *et al*. 2014). The second important collection is the bryophyte collection within the herbarium of the University of Belgrade (BEOU). It was established in the early 1990s (Vukojičić *et al*. 2011). The collection is estimated to have over 18000 bryophyte specimens. The greatest number of specimens was collected from Serbia, followed by other Balkan countries (Albania, Bosnia and Herzegovina, Croatia, Greece, Macedonia, Montenegro, Slovenia), as well as from the rest of Europe (Austria, the Czech Republic, France, Germany, Hungary, Italy, Spain). At the present time, work on the establishment of an e-database of the bryophyte collection within BEOU is in progress. The herbarium maintained by the Department of Biology and Ecology of Novi Sad University's Faculty of Sciences (BUNS) has 137 bryophyte specimens so far. Outside of Serbia, another important collection worth mentioning is the Balkan collection within the bryophyte collection of the Hungarian Natural History Museum in Budapest (BP). This collection numbers more than 5000 specimens collected from Serbia.

**Aggregation of data - Bryophyte Database.** All literature data (published up to December of 2016) and only digitalised herbarium specimens from Serbia (the BEOU bryophyte collection) were compiled to form a unique database on bryophyte distribution in Serbia. Additional data on the habitats and ecology of species were included. To date, the database contains 26471 records for species occurrences in Serbia - 23173 from the literature and 3298 from the herbarium. Altogether, 197 references were incorporated in it (Fig. 1). Not all records in the database are unique, i.e., some authors cited previous records for the same explored locality already included in the database.

A total of 1697 records for 311 taxa were obtained from 20 papers published during the early period. Although the greatest number of papers (92) appeared during the middle period, not many of them were strictly bryofloristic contributions, and for this reason only a moderate increase in the number of species was observed. In the middle period, records of 190 more taxa (within a total of 7030 records) were published, as were those of another 300 more taxa (within a total of 17701 records) in the modern period. In total, 85 papers treating the bryophyte flora and new country records have been published to date during so called modern period of bryophyte investigation in Serbia. With respect to the total number of findings and new country records, the modern period is without doubt the most productive one in the development of bryophyte science in Serbia (Figs. 2, 3). Thus, an increase in the total number of taxa by 76.6% (or 318 taxa) is evident when a check-list published at the beginning of the modern period (Gajić 1991) is compared with the last one published (Hodgetts 2015).

It is also worth mentioning that Sabovljević leads the Bryophyte Biology Research Group, which not only deals with flora investigation, but is also concerned with various aspects of bryophyte experimental biology. He has established the world's biggest *in vitro* collection of living bryophytes from all over the globe for the purpose of eco-physiological investigation and conservation of species. The collection at present numbers 259 species, but it is continuously growing (Sabovljević *et al*. 2014).

Although the current period has brought many new floristic contributions and the number of species has almost doubled, there are still many areas yet to be explored. In spite of the fact that the Serbian bryophyte flora is already considered to be rich in species, new country records are expected with continued exploration.

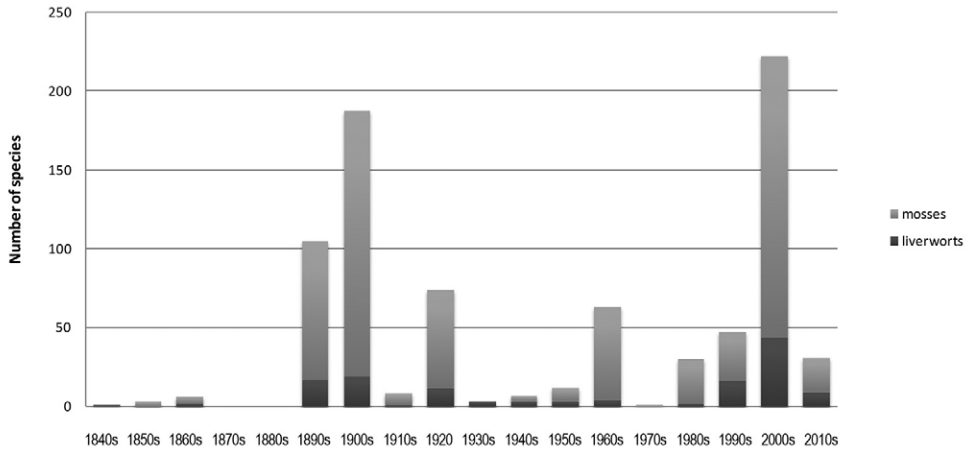


**Fig. 2.** Number of newly recorded bryophyte species in Serbia (by decades).

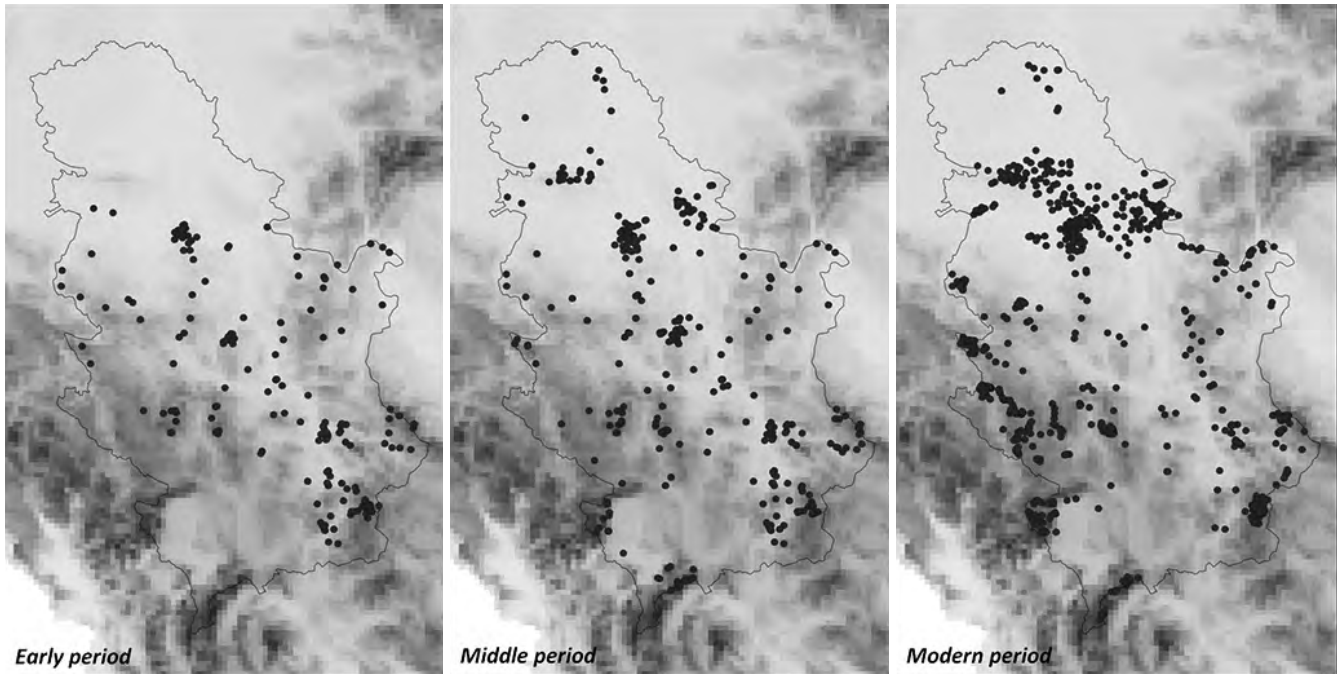


**Fig. 3.** Areas of research during three periods of bryophyte exploration in Serbia. Dots represent recording sites.

On the other hand, the records of certain species are doubtful and some should be deleted from the Serbian bryophyte flora. In closing, it should be stressed that ongoing research is important not only for more complete knowledge about the flora, species distribution, and ecology, but also for better recognition of rare and threatened species, proposal of protective measures, and establishment of areas important for conservation (e.g., important bryophyte areas - IBrA) (Papp 2008).

## CONCLUDING REMARKS

According to present knowledge, the bryophyte flora of Serbia includes a total of 797 species (661 mosses, 135 liverworts, and one hornwort). During the new wave of bryological research in Serbia, more than 300 new species records have so far been added to the bryophyte flora of Serbia. The rest can be regarded as historical records, which should be taken into account when

preparing research plan priorities and conservation actions. A further critical approach is needed to clear up questions about the presence of some species and resolve taxonomical/conservation issues.

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Botanica SERBICA

REZIME

# Pregled istraživanja briofita u Srbiji sa predstavljanjem odgovarajuće baze podataka

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Istraživanje flore briofita u Srbiji bilo je krajnje sporadično sve do kraja 19. veka, kada je grupa srednjoškolskih učitelja počela da ih istražuje. Može se reći da je ovo je bio prvi period intenzivnog istraživanja, koji je doneo brojne nove nalaze za zemlju. Nakon toga, mali broj istraživača bavio se isključivo proučavanjem briofita u Srbiji i većina horoloških podataka je dobijena iz vegetacijskih, ekoloških i paleobotaničkih studija. To je bio slučaj sve do početka 1990.-ih, kada je počeo procvat briologije u Srbiji, koji je doneo mnogo novih florističkih studija, kao i novih nalaza za zemlju. Danas, sa ukupno 797 vrsta, smatra se da Srbija ima veliki diverzitet briofita. Međutim, nastavak daljih istraživanja, kao i kritički osvrt na floru briofita su neophodni.

**Ključne reči:** mahovine, jetrenjače, trenutna saznanja, istorijat, Balkan, briologija