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Contribution to Understanding the Distribution of the Species *Campanula austroadriatica* D. Lakušić & Kovačić in Bosnia and Herzegovina

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Abstract

The paper offers an overview of the distribution of the endemic species *Campanula austroadriatica* D. Lakušić & Kovačić in Bosnia and Herzegovina, based on the revision of herbarium specimens from the herbarium of the National Museum in Sarajevo (SARA), literature data, and our own field research. Additionally, a brief morphological description and photographs of the species are provided. The species *Campanula austroadriatica* D. Lakušić & Kovačić is present in Bosnia and Herzegovina in 23 localities spread over 13 UTM squares, all localities are located within the Mediterranean biogeographical region.

Keywords: *Campanula austroadriatica* D. Lakušić & Kovačić, endemic species, distribution, habitat, Bosnia and Herzegovina.

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1. Introduction

The genus *Campanula* is the largest genus of the Campanulaceae family (Park et al., 2006). However, when it comes to the number of species and lower taxonomic categories, there is considerable disagreement, with estimates ranging from 350 to 450 species (Ančev, 1994; Lammers, 2007). These species are distributed from the Arctic and temperate zones of the Northern Hemisphere to the south to Eastern Africa, Southern Asia, and Northern Mexico. Presently, there are around 200 species of the genus Campanula in Europe (Fedorov and Kovanda, 1976). New species are constantly being described (Kovanda, 1999), and based on research, some change status (Lakušić and Conti, 2004). On the Balkan Peninsula, over 100 species and subspecies have been recorded (Fedorov and Kovanda, 1976; Kovačić, 2004; Škondrić et al., 2014), with a significant proportion being endemics (Kovačić, 2004; Škondrić et al., 2014). This is why the Balkan Peninsula is designated as one of the centers of diversity for the genus. In the past decade, several new species have been described in the Balkan Peninsula: *Campanula austroadriatica* D. Lakušić & Kovačić (Lakušić et al., 2013); *C. skanderbegii* Bogdanović, Brullo & D. Lakušić (Bogdanović et al., 2014a); *C. teutana* Bogdanović & Brullo (Bogdanović et al., 2014b); and *C. aureliana* Bogdanović, Rešetnik, Brullo & Shuka (Bogdanović et al., 2015).

According to the Flora of Bosnia and Herzegovina (Beck-Mannagetta et al., 1983), the genus *Campanula* is represented by 24 species from two sections: sect. *Campanula* and sect. Rapunculus Dumort. Abadžić and Šilić (1990) later supplemented this list with two more species for the territory of Bosnia and Herzegovina (*Campanula waldsteiniana* Schult. and *C. thyrsoides* L.), and Šoljan (2001) added another two species (*Campanula spicata* L. and *C. trichocalycina* Ten.). In the meantime, new species have been described for Bosnia and Herzegovina (Maslo and Boškailo, 2015) and certain changes in names have been made. Authors Lakušić et al. (2013) conducted a detailed phylogenetic study of the *Campanula pyramidalis* L. complex by analyzing molecular data obtained by sequencing nuclear internal transcribed spacers (ITS) and three non-coding chloroplast regions (psbA-trnH, psbZ-trnfM, trnG-trnS). The results of this study indicate the existence of three different groups of populations in the form of three well-supported phylogenetic branches in phylogenetic networks and trees. Specifically, the existence of a new species (*Campanula austroadriatica* D. Lakušić & Kovačić, sp. nov.) south of the Neretva River valley was noted. A herbarium specimen from the University of Belgrade Herbarium (BEOU) No. 31510 collected in the Risan locality, Boka Kotorska, Montenegro, was designated as the holotype of this species. *Campanula austroadriatica* is described as a long-lived plant with a densely interwoven rhizome from which several erect stems with numerous flowers emerge. The lower part of

the stem becomes woody. The leaves are serrated, somewhat fleshy, and the teeth have glandular edges. Basal leaves are ovate-heart-shaped to ovate-lanceolate. The upper leaves are sessile and taper towards the base. The widely bell-shaped flowers are almost sessile, clustered in a long inflorescence 30-100(-120) cm long. The corolla is bell-shaped, purple to light bluish-purple, usually with dark blue in the center, composed of five fused petals. There are five stamens. The fruit is a capsule with many small seeds, 0.9-1.0 x 0.4-0.5 mm in diameter. This species has been recorded in the following countries: Croatia (Nikolić, 2019), B&H (Maslo and Boškailo, 2015), Montenegro (Lakušić et al., 2013), and Albania (Barina et al., 2018).

The main goal of this paper is to contribute to the understanding of the distribution of the species *Campanula austroadriatica* D. Lakušić & Kovačić in Bosnia and Herzegovina.

2. Material and Methods

Data on the distribution of the species were collected based on available literature sources, analysis of herbarium material, and the authors field research conducted in the period from 2016 to 2022. The determination was made using the key: Nikolić (2019). Nomenclature is harmonized with the Euro+Med PlantBase (2006-2023), the information system for the vascular flora of Europe and the Mediterranean. All collected data were georeferenced using the ArcGIS 10.4 software program. For displaying the distribution of the given species, the UTM grid 10 x 10 km (Lampinen, 2001) was used with the dot method according to Walter and Straka (1970) for a more complete field coverage and ensuring a satisfactory level of exploration and thus objectivity in the representation of distribution status.

3. Results

The species *Campanula austroadriatica* D. Lakušić & Kovačić has been separated from the species Campanula pyramidalis L. in the territory of B&H (Maslo and Boškailo, 2015), where it is stated, that all findings of Campanula pyramidalis L. in Herzegovina are attributed to the species *Campanula austroadriatica* D. Lakušić & Kovačić. The first data on the presence of this species in the territory of B&H are mentioned by Vandas (1909), and then K. Malý (1910) confirmed it at the following locations: around Hrasno, Čapljina, Ravnog, and Zavala-Čvaljina. Autor Đuran in Beck-Mannageta (1983) mentions it for the area of Mountain Žaba near Hutovo. The following data are found after the year 2000, Maslo and Boškailo (2015) mention it for the following locations: Bivolje Polje, Počitelj, and one herbarium specimen is stored in the Herbarium of the National Museum of Bosnia and Herzegovina

(Čapljina: Počitelj, leg. et det. Boškailo, A. & Maslo, S., 22.10.2015, inv. no. 51435., SARA), and Boškailo et al. (2016) confirmed it at the locations: Ravno and near Ljubinj. Through new field research, it has been confirmed at the following locations: Čapljina - Hutovo blato, Neum - Klek, Neum, Klobuk (border crossing), Trebinje - Trebinjsko jezero, Trebinje - Stari Grad, Trebinje - near Donji Čičava, Trebinje – Skočigrm, Trebinje - Strujići, Čapljina - Cerovica, Čapljina - Dretelj, (Figure 1; Figure 2; Table 1).

Table 1: Findings of the species Campanula austroadriatica D. Lakušić & Kovačić in Bosnia and Herzegovina

No.	Wider locality	Narrower locality	Habitat	Coordinate	Altitude	Source	Year	UTM
1.	Neum	around Hrasna	-	42,95175 17,91657	335 m	Malý, 1910;	1910	YH36
2.	Čapljina	around Čapljine	fissures in limestone rocks	43,12214 17,72075	35 m	Malý, 1910; Field finding	1910	YH27
3.	Ravno	Ravno	fissures in limestone rocks	42,8792 17,9728	256 m	Malý, 1910; Field finding;	1910	YH45
4.	Ravno	Zavala-Čvaljina	fissures in limestone rocks	42,86832 17,97095	331 m	Malý, 1910; Field finding	1910	YH44
5.	Neum	Mt. Žaba	fissures in limestone rocks	42,95403 17,80015	391 m	Beck-Mannageta, 1983; Field finding	1983	YH26
6.	Čapljina	Bivolje Polje	fissures in vertical limestone rocks	43,15737 17,76030	47 m	Field finding; Maslo et Boškailo, 2015; Maslo in Nikolić, 2023	2015	YH28
7.	Čapljina	Bivolje Polje	fissures in vertical limestone rocks	43,15737 17,76030	47 m	SARA!; Field finding	2015	YH28
8.	Čapljina	Počitelj	fissures in vertical limestone rocks	43,14526 17,73430	34 m	Maslo et Boškailo, 2015; Maslo in Nikolić, 2023; Field finding	2015	YH27
9.	Ravno	Ravno	fissures in limestone rocks	42,89065 17,99765	327 m	Boškailo et al., 2016	2016	YH45

No.	Wider locality	Narrower locality	Habitat	Coordinate	Altitude	Source	Year	UTM
10.	Ljubinje	at Ljubinja	fissures in limestone rocks	42,92485 18,05620	573 m	Boškailo et al., 2016	2016	BN65
11.	Čapljina	Hutovo	fissures in limestone rocks	42,96708 17,79961	457 m	Field finding; Bukvić et al., 2020; Maslo in Nikolić, 2023;	2016	YH27
12.	Neum	Klek	fissures in limestone rocks	42,91230 17,62297	46 m	Field finding; Maslo in Nikolić, 2023	2016	YH15
13.	Neum	Neum	fissures in limestone rocks	42,92955 17,61008	51 m	Field finding	2016	YH15
14.	Trebinje	Klobuk (border crossing)	fissures in limestone rocks	42,71121 18,55403	854 m	Field finding	2016	BN93
15.	Trebinje	Trebinjsko jezero	fissures in limestone rocks	42,70336 18,39035	309 m	Field finding	2016	BN83
16.	Trebinje	Stari Grad	fissures in limestone rocks	42,71009 18,35116	274 m	Field finding	2016	BN83
17.	Trebinje	at Donjeg Čičava	fissures in limestone rocks	42,67095 18,34900	420 m	Field finding	2016	BN82
18.	Trebinje	Skočigrm	fissures in limestone rocks	42,68735 18,51973	427 m	Field finding	2016	BN92
19.	Trebinje	Strujići	fissures in limestone rocks	42,88998 17,99336	268 m	Field finding	2016	YH45
20.	Čapljina	Cerovica	fissures in limestone rocks	42,98161 17,79928	349 m	Field finding	2020	YH26
21.	Čapljina	Dretelj	fissures in limestone rocks	43,13108 17,72248	51 m	Field finding	2022	YH27
22.	Ravno	Orahov Do	fissures in limestone rocks	42,82767 17,92851	343 m	Field finding	2022	YH34
23	Ravno	Čvaljina	fissures in limestone rocks	42,868731 17,970421	354 m	Field finding	2022	YH45

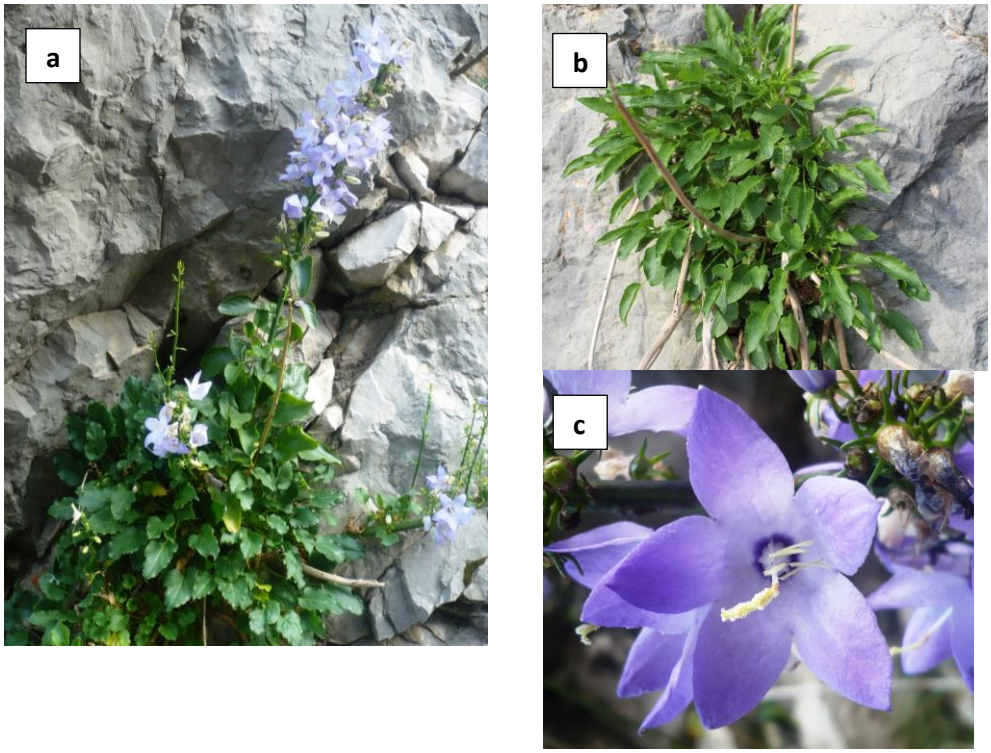

Figure 1: *Campanula austroadriatica* D. Lakušić & Kovačić: a) habitat of the species in the area of Klobuk near Trebinje; b) leaves; c) blossom (photo: Boškailo, A.)

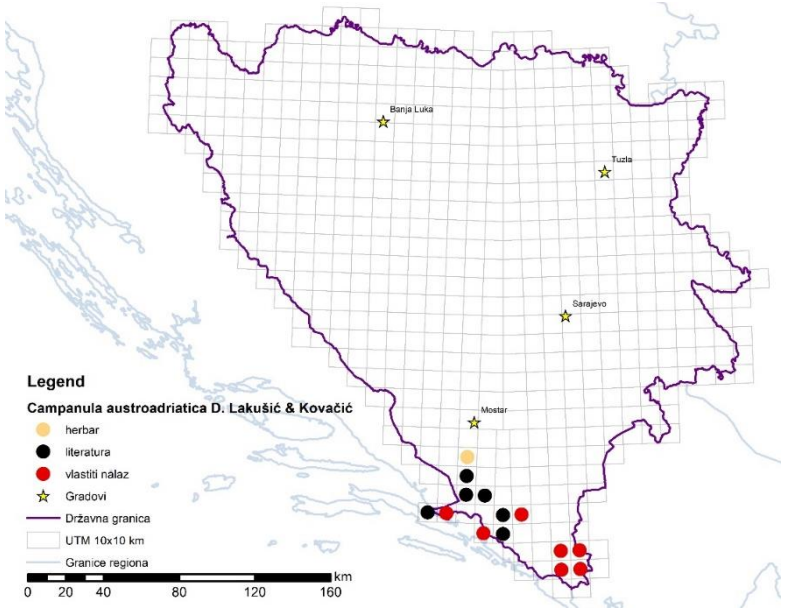

Figure 1: Distribution of the species *Campanula austroadriatica* D. Lakušić & Kovačić in Bosnia and Herzegovina

Based on the current analysis of available herbarium, literature data, and authors field research in B&H, 23 findings have been recorded in 13 UTM squares (Table 1; Figure 2). Populations of *Campanula austroadriatica* can be found within the vegetation of rock crevices (Asplenietea rupestris), and less often within the vegetation of sedges (Drypetea spinose), on limestone, on altitudes from 0 to 1.000 m. In urban habitats they can be found on old walls and fortresses (Lakušić et al., 2013).

Based on the provided map, it is evident that all findings are from the Mediterranean biogeographical region (European Environment Agency, 2002). Considering the fact that the species C. pyramidalis L. is listed on the Red List of protected species of flora and fauna of Republika Srpska (Anonymus, 2012) and on the Red List of the Federation of Bosnia and Herzegovina (Đug et al., 2013) under the category NT - Nearly threatened species, it is evident that the data from this study will represent a significant basis for assessing the threatened status of this species when creating the future Red List of Bosnia and Herzegovina.

4. Conclusions

The species *Campanula austroadriatica* D. Lakušić & Kovačić is present in Bosnia and Herzegovina across 23 distinct locations spread across 13 UTM squares, all situated within the Mediterranean biogeographical region. This species exhibits a preference for inhabiting cracks found within limestone rocks. The information highlights the importance of ongoing monitoring efforts, as there remains a significant likelihood of identifying additional locations where this species thrives within the Mediterranean biogeographical region. Such monitoring is crucial for understanding the distribution, ecology, and conservation needs of *Campanula austroadriatica* in Bosnia and Herzegovina.

5. References

1. Abažić, N., & Šilić, Č. (1990). About two additions to the flora of Bosnia and Herzegovina. Bulletin of the Society of Ecologists BIH, B, 5: 81-83.
2. Ančev, M. (1994). Campanula L. in the Bulgarian flora: taxonomy and evolution. God. Sofiisk. Univ. Kliment Ohridski, Biol. Fak., 2(85): 193-197.
3. Anonymus (2012). Red list of protected species of flora and fauna of the Republic of Srpska. Available at: https://nasljedje.org/wp-content/uploads/2018/06/Crvena_lista.pdf.

4. Barina, Z., Somogyi, G., Pifk ó, D. & Rakaj, M. (2018). Checklist of vascular plants of Albania. Phytotaxa 378(1): 1-339.
5. Beck-Mannagetta, G., Malý, K., Bjelčić, Ž. (1983). Flora Bosnae et Hercegovinae. IV Sympetalae Pars 4. Zemaljski muzej u Sarajevu, Posebna izdanja, knjiga 4. Sarajevo.
6. Bogdanović, S., Brullo, S., Rešetnik, I., Lakušić, D., Šatović, Z. & Liber, Z. (2014a). Campanula skanderbegii: molecular and morphological evidence of a new Campanula species (Campanulaceae) endemic to Albania. Systematic Botany 39: 1250-1260.
7. Bogdanović, S., Brullo, C., & Lakušić, D. (2014a). Campanula skanderbegii (Campanulaceae), a new species from Albania. PhytoKeys, (35): 65-73.
8. Bogdanović, S., Brullo, S., Rešetnik, I., Šatović, Z. & Liber, Z. (2014b). Campanula teutana, a new isophyllous Campanula (Campanulaceae) from the Adriatic region. Phytotaxa 162, 1-17.
9. Bogdanović, S., Rešetnik, I., Brullo, S., & Shuka, L. (2015). Campanula aureliana (Campanulaceae), a new species from Albania. Plant Systematics and Evolution 301: 1555-1567.
10. Boškailo, A., Mašić, E., Imamović, M., Avdibašić, A., Selimić, A. & Podrug, A. (2016). Report of the botanical section: Diversity of cyanobacteria, algae and vascular flora in the wider area of Stolac. Stolac: Association biology students in Bosnia and Herzegovina.
11. Bukvić, V., Boškailo, A., Drešković, N., Zovko, N., Boškailo, S. (2020). Plants PP Hutovo blato. Scientific monograph. University of Herzegovina, Mostar.
12. Đug, S., Muratović, E., Drešković, E., Boškailo, A., Dudević, S. (2013). Red list of the flora of the Federation of Bosnia and Herzegovina. Draft report - Proposal. Sarajevo: Project of Forest and Mountain Protected Areas, "NGO Green way" and "Federal Ministry of Environment and Tourism", pp. 1- 347.
13. Euro+Med PlantBase - the information resource for Euro-Mediterranean plant diversity. Berlin. Available from: http://ww2.bgbm.org/EuroPlusMed/query.asp [Accessed 10 February 2024].
14. European Environment Agency (2002). Europe's biodiversity – biogeographical regions and seas. EEA Report No1/2002.
15. Fedorov, A.A. & Kovanda, M. (1976). Campanula L. In: Tutin, T.G. i sur. (eds): Flora Europaea 4. Cambridge: Cambridge University Press, pp. 4-93.
16. Kovačić, S. (2004). The genus Campanula L. (Campanulaceae) in Croatia, circum-Adriatic and west Balkan region. Zagreb: Acta Botanica Croatica 63: 171-202.
17. Kovanda, M. (1999). Campanula x iserana (C. rhomboidalis x C. rotundifolia), a new hybrid in Campanula. Thaiszia - J. Bot. Košice 9: 15-18.

18. Lakušić, D. & Conti, F. (2004). Asyneuma pichleri (Campanulaceae), a neglected species of the Balkan peninsula. Plant Syst. Evol. 247: 23–36.
19. Lakušić, D., Liber, Z., Nikolić, T., Surina, B., Kovačić, S., Bogdanović, S. & Stefanović, S. (2013). Molecular phylogeny of the Campanula pyramidalis species complex (Campanulaceae) inferred from chloroplast and nuclear non-coding sequences and its taxonomic implications. Taxon 62: 505-524.
20. Lammers, T.G. (2007). Campanulaceae. In: Kubitzki K. (ed): The families and genera of vascular plants. Vol. 8. Springer pp. 26-56, Berlin.
21. Lampinen, R. (2001). Universal transverse mercator (UTM) and military grid reference system (MGRS). Avaible from: http://www.luomus.fi/en/utm–mgrs–atlas–florae–europaeae. (avaible to: 17.01.2003).
22. Malý, K. (1910). Prilozi za floru Bosne i Hercegovine 2. Sarajevo: Glasnik Zemaljskog Muzeja Bosne i Hercegovine, 22: 685-694.
23. Maslo, S. & Boškailo, A. (2015). Južnojadranska zvončika Campanula austroadriatica D. Lakušić & Kovačić – nova vrsta u flori Bosne i Hercegovine. Glasnik Hrvatskog botaničkog društva 3(3): 33-34.
24. Nikolić, T. (2019). Flora Croatica: Vaskularna flora Republike Hrvatske. Vol. 4. Zgreb: Alfa d.d., Zagreb.
25. Nikolić, T. (ed.) (2023). Flora Croatica baza podataka - Alhohtone biljke On-Line (http://hirc.botanic.hr/fcd/InvazivneVrste). Botanički zavod, Prirodoslovno-matematički fakultet, Sveučilište u Zagrebu, Zagreb.
26. Park, J.M., Kovačić, S., Liber, Z., Eddie, W.M. & Schneeweiss, G.M. (2006). Phylogeny and biogeography of isophyllous species of Campanula (Campanulaceae) in the Mediterranean area. Systematic Botany, 31(4): 862-880.
27. Škondrić, S., Aleksić, J.M. & Lakušić, D. (2014). Campanula cichoracea (Campanulaceae), a neglected species from the Balkan-Carpathian C. lingulata complex as inferred from molecular and morphological characters. Willdenowia 44: 77–96.
28. Šoljan, D. (2001). Distribution of rare and endangered species of genus Campanula L. in Bosnia and Herzegovina. Razprave IV. Ljubljana: Razreda SAZU, 42 (2): 229-241.
29. Vandas, C. (1909). Reliquiae Formánekianae. Enumeratio critica plantarum vascularum, quam itineribus in Haemo peninsula et Asia Minore (Bithynia) factis collegit Dr. Ed. Formánek. Jos. Jelínek, Brunae: Comitiorum Marchionatus Moraviae.
30. Walter, H. & Straka, H. (1970). Arealkunde. Floristich–historiche Geobotanik. In: Walter, H. (eds.): Einfürung in die Phytologie III/2. Stuttgart: Eugen Ulmer.

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Endemic and Endangered Species of the Drina National Park

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Abstract

In the eastern part of Bosnia and Herzegovina, on the territory of the Municipality of Srebrenica, in the middle course of the Drina River, lies the Drina National Park. Based on years of field research and existing literature sources, 635 taxa of vascular plants were identified in NP "Drina." Data analysis revealed 55 endemic taxa. Moreover, 43 taxa are included in the preliminary Red List of Bosnia and Herzegovina, 34 taxa are in the preliminary Red List of the Flora of the Federation of Bosnia and Herzegovina, while 48 taxa are in the Red List of the Republic of Srpska. The IUCN list includes 14 taxa, while 12 are in the CITES list. Particular value is added to NP "Drina" by the presence of Pančić spruce, an endemic, tertiary relict species.

Keywords: endemic species, endangered species, relict species, "Drina" National Park.

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1. Introduction

On the territory of the Municipality of Srebrenica, in the middle course of the Drina River, lies the Drina National Park, spreading over 6,315.32 ha. The area forms a unique complex covering the Stari Vlah region and is also part of the central belt of the Dinaric Alps (Panić, 2015). The protected area essentially comprises the gorge-canyon valley of the Drina River, including Perućac Lake and the mountain area of Sušica. The Drina National Park stretches 11 km south to north and 19 km west to east (Petrović, 2018). The highest point in NP "Drina" is located north of Luka village on the Grad viewpoint and measures 1,267 m.a.s.l. The lowest point is downstream of the river and is 291 m.a.s.l. (Panić, 2015).

The complex and varied geological, geomorphological, and pedological structure and specific climatic and vegetation characteristics have contributed to the formation of a rather picturesque landscape along the entire course of the Drina River. The most interesting part is the canyon-gorge valley of the Drina River with its grandiose over 1000 m high limestone sections. The Drina River Canyon, with discovery sites of Pančić spruce and a considerable number of endemic and relict species, is a unique environment in the Drina National Park. The landscape value of the Drina River Canyon is contributed by the thermophile forests of downy oak and hop-hornbeam, hop-hornbeam and manna ash, black pine forests, limestone cracks, and creeps. The Drina River Canyon is among Europe's most conserved parts of nature (Petronić, 2015). The area has been protected under the Drina National Park Law and the Study for the Proclamation of Protected Area - NP Drina adopted by the National Assembly of the Republic of Srpska ("Official Gazette of the Republic of Srpska" No. 63/17).

2. Material and Methods

The paper draws upon existing literature sources showing the diversity of the vascular flora Petronić (2015); endemic taxa of vascular plants were identified according to Lubarda et al. (2014), Šilić (1990), Šoljan (2023). The status of endangered species and levels of conservation are given according to the preliminary Red List of Endangered Species of Bosnia and Herzegovina (Šilić, 1996), the Red List of the RS (2012), the Decree on Strictly Protected and Protected Wild Plant Species of the RS (2020), the Red List of Flora of the FBiH (Đug et al. 2013), CITES (2023) and IUCN (2023). Species names have been harmonized with the Euro+Med PlantBase nomenclature (2006–2023). The species have been classified by taxonomic rank and family according to Tatić and Blečić (1996).

3. Results

Based on years of field research and existing literature sources (Beck, 1903, 1927; Maly, 1936: Plavšić, 1936, 1937; Fukarek, 1951), 635 taxa of vascular plants were identified in the area of NP "Drina." Endemic and endangered vascular flora taxa were singled out from the NP "Drina" inventory (Petronić, 2015) and shown in (Table 1.)

Table 1. List of endemic and endangered species from classes Magnoliopsida (subclasses Asteridae, Rosidae, Dilleniidae, Ranunculidae, Caryophyllidae) and Liliopsida (subclasses Liliidae and Commelinidae) in the Drina National Park

SPECIES	E	PRLBIH	RLFBiH	RLRS	SPSRS	CITES	IUCN
Class PINOPSIDA							
Pinaceae							
***Picea omorika* (Pančić) Purkynê**			NT				EN
Class: MAGNOLIOPSIDA							
SUBCLASS ASTERIDAE							
Asteraceae							
Centaurea derventana Vis. & Pančić	+	V	DD	+			
Cirsium candelabrum Griseb.	+						
Cirsium waldsteini Rouy	+						
Hieracium vilosum Jacq.	+						
Hieracium waldsteinii Tausch subsp. waldsteinii	+	R	EN	+			
Jurinea mollis (L.) Rchb.	+						
Senecio squalidus subsp. rupestris (Waldst. & Kit.) Greuter	+						
Telekia speciosa (Schreb.) Baumg.		V	VU	+			
Acanthaceae							
Acanthus hungaricus (Borbás)Baen.	+	R		+			
Boraginaceae							
Onosma stellulata Waldst. & Kit.	+	R	LC	+			
Campanulaceae							
Edraianthus graminifolius (L.) A. DC.	+			+			
Dipsacaceae							
Scabiosa cinerea Lam. subsp. *cinerea*	+	R	LC				
Scabiosa ochroleuca L.				+			
Gentianaceae							
Gentianella ciliata (L.) Borkh.		R	DD				
Lamiaceae							
Clinopodium alpinum subsp. *hungaricum* (Simonk.) Govaerts	+						
Clinopodium menthifolium (Host) Stace subsp. *menthifolium*	+						
Clinopodium thymifolium (Scop.) Kuntze	+			+			
Satureja subspicata Bartl. Ex Vis. subsp. *subspicata*	+	V	LC	+			
Stachys anisochila Vis. & Pancic	+	R		+			
Thymus praecox subsp. *jankae* (Čelak.) Jalas	+			+			
Orobanchaceae							
Melampyrum hoermannianum K. Malý	+	V		+			
Rinanthus rumelicus Velen.	+						
Plantaginaceae							
Digitalis lanata Ehrh.	+		VU				
Callitriche cophocarpa Sendtn.				+			

SPECIES	E	PRLBiH	RLFBiH	RLRS	SPSRS	CITES	IUCN
Rubiaceae							
Asperula taurina L.				+			
Asperula aristata subsp. *scabra* (J. Presl & C. Presl) Nyman	+						
Scrophulariaceae							
Scrophularia heterophylla subsp. *laciniata* (Waldst. & Kit.) Maire & Petitm.	+	R	EN	+			
Scrophularia scopolii Hoppe		R		+			
Valerianaceae							
Valeriana tripteris L.				+			
SUBCLASS ROSIDAE							
Acearceae							
Acer hyrcanum subsp. *intermedium* (Pančić) Bornm	+	R	EN	+			
Acer obtusatum Willd	+						
Apiaceae							
Athamanta turbith subsp. *haynaldii* (Borbás & R. Uechtr.) Tutin	+	R	EN	+			
Eryngium amethystinum L.	+						
Seseli rigidum Waldst. & Kit.	+						
Pimpinella serbica (Vis.) Benth. & Hook.f. ex Drude	+	R	EN	+			
Fabaceae							
Cytisus tommasinii Vis.	+	R	VU	+			
Genista januensis Viv.	+						
Genista sylvestris subsp. *dalmatica* (Bartl.) H. Lindb.	+			+			
Dorycnium pentaphyllum subsp . *germanicum* (Gremli) Gams	+						
Lathyrus laevigatus (Waldst. & Kit.) Gren		V		+			
Vicia oroboides Wulfen	+	R	LC	+			LC
Rhamnaceae							
Rhamnus alpina subsp. *fallax* (Boiss.) Maire & Petitm.	+						
Rosaceae							
Sorbus austriaca (Beck) Prain & al.		R		+			LC
Sanguisorba officinalis L.				+			LC
Rutaceae							
Dictamnus albus L.				+			
Saxifragaceae							
Saxifraga marginata Sternb.	+	R	NT	+			
SUBCLASS DILLENIIDAE							
Brassicaceae							
Arabis procurrens Waldst. & Kit.	+			+			
Erysimum carniolicum Dolliner	+						
Erysimum linariifolium Tausch	+						
Noccaea praecox (Wulfen) F. K. Mey.	+						
Ericaceae							
Erica carnea L.	+						
Pyrola rotundifolia L.		R	DD	+			
Primulaceae							
Cyclamen purpurascens Mill.		V	LC			+	LC
Primula elatior subsp. *intricate* (Gren. & Godr.) Ludi	+	E	LC	+			
Lysimachia nemorum L.				+			
Thymelaeaceae							
Daphne laureola		R		+			
Daphne malyana Blečić	+	R	EN	+			

SPECIES	E	PRLBIH	RLFBiH	RLRS	SPSRS	CITES	IUCN
SUBCLASS RANUNCULIDAE							
Berberidaceae							
Epimedium alpinum L.	+						
Papaveraceae							
Pseudofumaria alba (Mill.) Lidén	+			+			
Pseudofumaria alba subsp. *leiosperma* (P. Conrath) Lidén	+	R	EN	+			
Ranunculaceae							
Helleborus odorus Willd.	+						
Hepatica nobilis Schreb.	+	V	VU				LC
SUBCLASS CARYOPHYLLIDAE							
Caryophyllaceae							
Cerastium decalvans Schloss. & Vuk.	+	V	LC				
Dianthus giganteus subsp. *croaticus* (Borbás) Tutin	+	V	LC	+			
Dianthus petraeus Waldst. & Kit. subsp. *petraeus*	+	V	LC	+			
Dianthus sylvestris subsp. *bertiscus* Rech. f.	+						
Silene sendtneri Boiss.	+	R	LC	+			
SUBCLASS LILIDAE							
Amaryllidaceae							
Galanthus nivalis L.		V	LC			+	NT
Asparagaceae							
Ruscus aculeatus L.				+			
Iridaceae							
Iris reichenbachii Heuff.	+	R	LC		+		
Liliaceae							
Convallaria majalis L.		V		+			LC
Erythronium dens-canis L.		V	LC				
Lilium martagon L.		V	LC				
Orchidaceae							
Cephalanthera damasonium (Mill.) Druce		R			+	+	LC
Cephalanthera longifolia (L.) R. M. Fritsch		R	VU		+	+	LC
Cephalanthera rubra (L.) Rich.		R	VU		+	+	LC
Dactylorhiza maculata (L.) Soó subsp. *maculata*		V		+		+	LC
Epipactis helleborine (L.) Crantz						+	
Listera ovata (L.) R. Br.						+	
Neottia nidus-avis (L.) Rich.						+	
Neotinea ustulata (L.) R. M. Bateman, Pridgeon & M. W. Chase				+		+	LC
Orchis mascula subsp. *speciosa* (Mutel) Hegi		V		+		+	LC
Platanthera bifolia (L.) Rich.		R	NT		+	+	LC
Traunsteinera globosa (L.) Rchb.			NT	+			
SUBCLASS COMMELINIDAE							
Cyperaceae							
Eriophorum latifolium Hoppe				+			
Poaceae							
Calamagrostis villosa (Chaix) J. F. Gmel.				+			
Poa stiriaca Dörfl.				+			
Sesleria autumnalis (Scop.) F. W Schultz	+						
Sesleria juncifolia Suffren							

Legend:
E – endemic, PRLBIH – Preliminary Red List of Bosnia and Herzegovina, RLFBIH – Red List of the Flora of the Federation of Bosnia and Herzegovina, RLRS –Red List of the Republic of Srpska, SPSRS – Strictly protected species of the Republic of Srpska, CITES - Convention on International Trade in Endangered Species of Wild Fauna and Flora, IUCN – International Union for Conservation of Nature

According to the preliminary Red List of Endangered Species of Bosnia and Herzegovina (Šilić, 1996), 43 taxa have been singled out, of which 16 are in the category of endangered or vulnerable species (V), 26 are rare or potentially endangered species (R), and one subspecies is in category E (likely extinct).

Class Pinopsida includes Pančić spruce, an endemic-relic species, which is found in the preliminary Red List of Bosnia and Herzegovina in the category of rare or potentially endangered species (R), in the Red List of Flora of the Federation of Bosnia and Herzegovina in the category of near threatened species (NT), is not found in the endangered category of the Red List of Strictly Protected Species of Republic of Srpska, and is classified in endangered species category (EN) in the IUCN list.

Class Magnoliopsida is represented by five subclasses. Subclass Asteridae includes 30 taxa, of which 20 (66.6%) are endemic, 13 (43.3%) are in the preliminary Red List of Bosnia and Herzegovina, 9 (30%) are in the Red List of the Federation of Bosnia and Herzegovina, while 17 taxa (56%) are in the Red List of Republic of Srpska. In subclass Asteridae, no taxa are found in the category of endangered species in the SPSRS, CITES, or IUCN list. The most represented taxa are from the Asteraceae family. Eight taxa were registered, of which seven are endemic (87.5%), and the Preliminary Red List of Bosnia and Herzegovina, the Red List of the Flora of the Federation of Bosnia and Herzegovina, and the Red List of Republic of Srpska include three taxa (37.5%) each. Of the registered taxa from the Lamiaceae family (6), all are endemic, two (33%) are in the Preliminary Red List of Bosnia and Herzegovina, one (16.67%) is in the Red List of the Flora of the Federation of Bosnia and Herzegovina, while four (66%) are in the Red List of Republic of Srpska (Figure. 1.)

Subclass Rosidae includes 17 taxa, of which 13 are endemic (76%), eight (47.06%) are in the preliminary Red List of Bosnia and Herzegovina, six (35.29%) are in the Red List of the Flora of the Federation of Bosnia and Herzegovina, 11 (64%) are in the Red List of the Republic of Srpska. Three taxa (17.6%) are in the IUCN list in the least concern category. The most numerous taxa in this subclass are from the Fabaceae family, with six taxa, of which five (83%) are endemic. Three taxa (50%) are in the Preliminary Red List of Bosnia and Herzegovina, two (33.33%) are in the Red List of the Flora of the Federation of Bosnia and Herzegovina, and four taxa (66%) are in the Red List of Republic of Srpska, while one (16.67%) is in the IUCN list in the least concern category.

Subclass Dilleniidae includes 12 taxa, of which eight (66%) are endemic. Six taxa (50%) are in the preliminary Red List of Bosnia and Herzegovina, four taxa (33.33%) are in the Red List of the Flora of the Federation of Bosnia and Herzegovina, while

seven taxa (58%) are in the Red List of Republic of Srpska. The CITES list includes one taxon (8.3%). One taxon (8.3%) is also found in the least concern category of the IUCN list. From the Brassicaceae family, there are four endemic taxa, and one taxon (25%) is in the Red List of the Republic of Srpska.

Subclass Ranunculidae includes five taxa, all of which are endemic. The preliminary Red List of Bosnia and Herzegovina, the Red List of the Flora of the Federation of Bosnia and Herzegovina, and the Red List of the Republic of Srpska include two taxa (40%), while one taxon (20%) is in the IUCN list.

The Caryophylaceae family, subclass Caryophyllidae, has five taxa represented, all of which are endemic. Four taxa (80%) are in the Preliminary Red List of Bosnia and Herzegovina and the Red List of Flora of the Federation of Bosnia and Herzegovina, while three taxa (60%) are in the Red List of the Republic of Srpska.

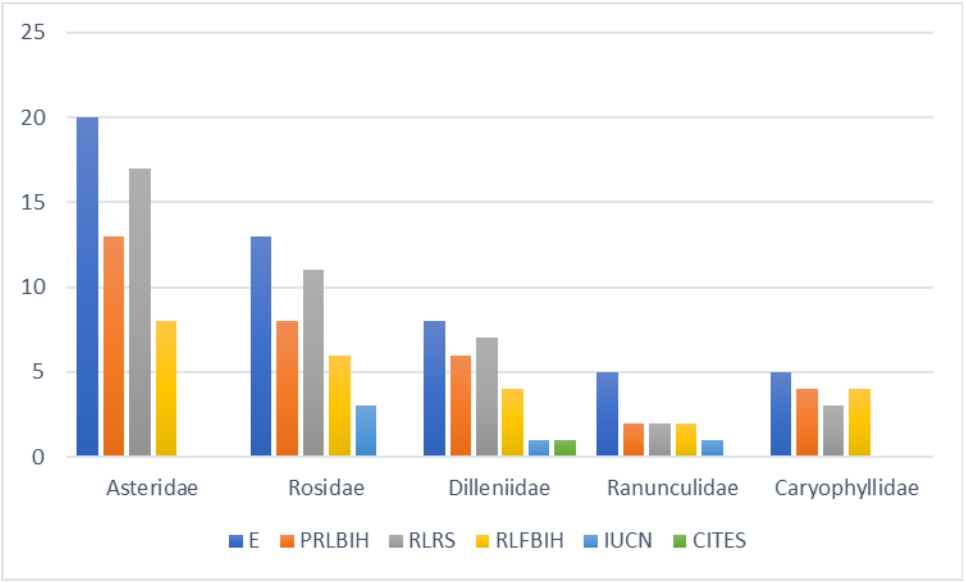

Figure 1. Representation of taxa by different evaluation systems and conservation of species in subclasses of Class Magnoliopsida

Class Liliopsida is represented by two subclasses, Lilidae and Commelinidae. Subclass Lilidae includes 17 taxa, of which one (5.88%) is endemic. There are 11 taxa (64.71) in the preliminary Red List of Bosnia and Herzegovina, eight taxa (47.06%) in the Red List of the Flora of the Federation of Bosnia and Herzegovina, and six taxa (35.29%) in the Red List of Republic of Srpska, five taxa (29.41%) are strictly protected in Republic of Srpska, while eight taxa (47.06%) are in the IUCN list. The CITES list includes 11 taxa (64.7%). The most numerous species are from the Orchidaceae family, of which ten taxa (90%) are in the CITES list, and six taxa (54.54%) are in the

preliminary Red List of Bosnia and Herzegovina. The Red List of Flora of the Federation of Bosnia and Herzegovina, the Red List of the Republic of Srpska, and the List of strictly protected species in the Republic of Srpska include four taxa (36.36%) each. The IUCN list includes six taxa (54.54%) as least concern. Taxa from subclass Commelilnidae include one endemic (20%) and three strictly protected species (60%) in the Republic of Srpska (Figure 2.).

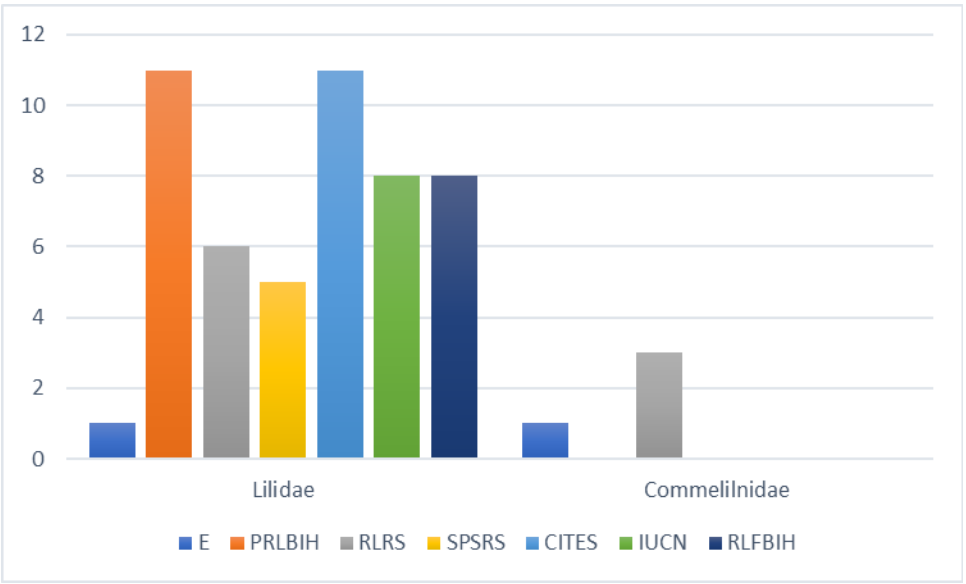

Figure 2. Representation of taxa by different evaluation systems and conservation of species in subclasses of Class Liliopsida

4. Discussion

Fifty-four endemic species have been registered in the studied area. The endemic species are dominated by mesoendemic species, while stenoendemic species are much rarer. The number of endemics decreases from rock cracks and creeps toward forests, thickets, and meadows. The following endemic species are represented: *Acer hyrcanum* subsp. *intermedium*, *Acer obtusatum*, *Athamanta turbith* subsp. *haynaldii*, *Cytisus tommasinii*, *Cirsium candelabrum*, *Cirsium waldsteinii*, *Daphne malyana*, *Iris reichenbachii*, *Clinopodium thymifolium*, *Pseudofumaria alba* subsp. *leiosperma*, *Satureja subspicata* subsp. *subspicata* and others.

The exceptional floristic importance of the Drina National Park is reflected in the presence of vascular plant species found in the preliminary Red List of Bosnia and Herzegovina, the Red List of Flora of the Federation of Bosnia and Herzegovina and the Decree on the Red List of Endangered Plant and Animal Species of Republic of

Srpska. All species give particular significance to the flora and vegetation of the studied area. These are endemic, rare and endangered species protected by national and global regulations.

Species from the preliminary Red List of Bosnia and Herzegovina include *Picea omorika* (R), *Cerastium decalvans* (V), *Dianthus petraeus* (R), *Silene sendtneri* (R), *Saxifraga marginata* (R), *Pyrola rotundifolia* (R), *Hieracium waldsteinii* (R), *Lilium martagon* (V), *Erythronium dens-canis* (V) *Convallaria majalis* (V), *Plathanthera bifolia* (R), *Gentianella ciliata* (R) and others.

Species from the Red List of Flora of the Federation of Bosnia and Herzegovina include *Telekia speciosa* (VU), *Digitalis lanata* (VU), *Scrophularia heterophylla* subsp. *laciniata* (EN), *Pimpinella serbica,* and others.

According to the Decree on the Red List of Endangered Plant and Animal Species of Republic of Srpska, the following species are protected: *Acanthus hungaricus*, *Allium victorialis*, *Arabis procurrens*, *Asperula taurina, Callitriche cophocarpa*, *Campanula sibirica*, *Equisetum sylvaticum*, *Primula elatior subsp. intricata*, *Vicia oroboides,* and others.

In the flora of the studied area, the following species from the Washington Convention CITES list were identified: *Galanthus nivalis*, *Cephalanthera longifolia*, *Cephalanthera rubra*, *Dactylorhiza maculata* subsp. *maculata*, *Anacamptis morio*, *Traunsteinera globosa*, *Epipactis helleborine*, *Orchis mascula* subsp. *speciosa,* and others. These species are listed in Appendix II of the CITES Convention. They are currently not threatened with extinction and are protected, but trade in specimens from natural habitats is prohibited, while it is allowed in nurseries and cultures. These species are endangered due to their decorative and medicinal value.

5. Conclusion

In the eastern part of Bosnia and Herzegovina, on the territory of the Municipality of Srebrenica, in the middle course of the Drina River, lies the Drina National Park. Based on years of field research and existing literature sources, 635 taxa of vascular plants were identified in the area of NP "Drina." Data analysis revealed 55 endemic taxa. Moreover, 43 taxa are included in the preliminary Red List of Bosnia and Herzegovina, 34 taxa are in the Red List of the Flora of the Federation of Bosnia and Herzegovina, while 48 taxa are in the Red List of the Republic of Srpska. The IUCN list includes 14 taxa, while 12 are in the CITES list. Particular value is added to NP "Drina" by the presence of Pančić spruce, an endemic, tertiary relict species.

6. Literature

1. Beck, G. (1903). Flora Bosne, Hercegovine i novopazarskog sandžaka. I dio, Sarajevo: Zemaljska štamparija.
2. Beck, G. (1927). Flora Bosnia, Herzegovina et regions Novi Pazar. II. Choripetalae. Beograd, Sarajevo: Državna štamparija.
3. Brković, D. (2015). Vaskularna flora brdsko-planinskog područja severozapadne Srbije- ekološko fitogeografska studija. Univerzitet u Beogradu Biološki fakultet, Beograd.
4. CITES. (2023) Convention on International Trade in Endangered Species of Wild Fauna and Flora [Online]. Available: https://cites.org/eng [accessed on 03 November 2023].
5. Đug, S., Muratović, E., Drešković, E., Boškailo, A. & Dudević, S. (2013). Crvena lista flore Federacije Bosne i Hercegovine. Nacrt izvještaja – Prijedlog. p. 97. Sarajevo: Projekat Šumskih i planinskih zaštićenih područja, „NVO Green way" i „Federalnog ministarstva za okoliš i turizam".
6. Euro+Med (2006-): Euro+Med PlantBase – the information resource for Euro-Mediterranean plant diversity. Published on the Internet http://ww2.bgbm.org/EuroPlusMed/ [accessed on 08 December 2023].
7. Fukarek, P. (1951). Današnje rasprostranjenje Pančićeve omorike (*Picea omorika* Pančić) i neki podaci o njenim sastojinama. *God. Biol. Inst*. II. Sarajevo.
8. IUCN. (2023) The IUCN Red List of Threatened Species [Online]. Available: https://www.iucnredlist.org/ [accessed on 03 December 2023].
9. Lakušić, R. & Redžić, S. (1991). Flora i vegetacija vaskularnih biljaka u refugijalno-reliktnim ekosistemima kanjona rijeke Drine i njenih pritoka. *Bilten Društva ekologa BiH* 6: 25-73.
10. Lubarda, B., Stupar, V., Milanović, Đ. & Stevanović, V. (2014). Chorological characterization and distribution of the Balkan endemic vascular flora in Bosnia and Herzegovina. *Botanica Serbica* 38(1): 167–184.
11. Maly, K. (1936). Beiträge zur Kenntnis der Picea Omorika. *Glasnik Zemaljskog muzeja u BiH*. XLVI, sveska za prirodne nauke, Sarajevo.
12. Mataruga, M. & Milanović, Đ. (2020). Prirodne populacije Pančićeve omorike u Republici Srpskoj (Bosna i Hercegovina). *Glasnik Šumarskog fakulteta Univerziteta u Banja Luci* 30: 77-113.
13. Nezirović, S. & Avdić, B. (2019). Spatial distibution of turist resources in Drina Nacional park. *Journal for Geography* 14-2: 23-38.
14. Petronić, S., Kovačević, D., Kadić, J., Radošević, D., Panić, G., Todorović, S., Travar, J., Okilj, M., Dragaš. M., Gligorić, S., Srdić, Lj. & Parežanin, Lj. (2015). Nacionalni park „Drina", Studija za proglašenje zaštićenog područja. Republički zavod za zaštitu kulturno-istorijskog i prirodnog nasljeđa, Banja Luka.

15. Petrović, D. (2018). Svojstva drveta Omorike (Picea omorika (Pančić) Purkině) iz prirodnih sastojina i kultura na području Republike Srpske. Banja Luka.
16. Plavšić, S. (1936). Staništa Pančićeve omorike na levoj obali Drine. *Glasnik Zemaljskog muzeja u BiH*, God. XLVIII, sv. 2, Sarajevo.
17. Plavšić, S. (1937). Neue Befunde über die Verbreitung von Picea Omorika. *Osterreichische botanische Zeitschrift*. Heft. 7, Band. 86, Wien.
18. Službeni glasnik Republike Srpske 65/20
19. Šilić, Č. (1990). Endemične biljke. III izdanje. Sarajevo: IP „Svjetlost“; Zavod za udžbenike i nastavna sredstva; Beograd
20. Šilić, Č. (1996). *S*pisak biljnih vrsta (Pteridophyta i Spermatophyta) za Crvenu knjigu Bosne i Hercegovine. *Glasnik Zemaljskog muzeja BiH* 31: 323-367.
21. Šoljan, D. (2023). Endemi flore planina u okolici Sarajeva. Dobra knjiga, Sarajevo.
22. Tatić, B. & Blećić, V. (1996). Sistematika i filogenija viših biljaka. Zavod za udžbenike i nastavna sredstva, Beograd.
23. Uredba o Crvenoj listi zaštićenih vrsta flore i faune Republike Srpske (2012). [Online]. Available:http://bih-chm-cbd.ba/wp-content/uploads/2020/11/uredbacrvenalista-4.pdf. [accessed on 07 December 2023].

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Reproductive Performance of Male Rainbow Trout *Oncorhynchus mykiss* (Walbaum, 1792) Feeding with Food from Two Different Manufacturers

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Abstract

This study was carried out to compare the growth and development of testicles in rainbow trout, *Oncorhynchus mykiss* (Walbaum, 1792) at the Royal fish and Magazin Maprim fish farms using pellet fish feed of various manufacturers. Two groups with 30 individuals of the same age were examined. The males from the Royal fish farm were fed with Skretting feed while the Magazin Maprim fish farm used Coppens feed. Fish were fed twice a day at 5% body weight basis. Physicochemical parameters of water were within acceptable values for this species. The values of total length and total weight of the males from the Royal fish farm fed with Skretting feed showed a significant statistical difference compared to the males from the Magazin Maprim fish farm fed with Coppens feed. Also, mean weight of the testicles and gonadosomatic index of the males fed with Skretting feed did not show a statistically significant difference compared to the weight of the testicles and gonadosomatic indexof the males fed with Coppens feed. Histological assay of the testicles of rainbow trout subjected to experimental feeds showed a normal cell growth and spermatogenesis in both groups. The results indicate that there are differences in

the growth of rainbow trout between the observed groups in favor of Skretting feed manufacturer, which should be taken into account when selecting the feed for a more productive farming.

Keywords: *rainbow trout, growth, gonadosomatic index, testicles histology, pellet fish food.*

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1. Introduction

Aquaculture in Bosnia and Herzegovina is in constant development, representing the fastest growing sector of animal agriculture. The growing trend of production has continued from year to year according to the available data of B&H Agency for Statistics. The most important fish species raised at fish farms in the Federation of Bosnia and Herzegovina is rainbow trout, *Oncorhynchus mykiss* (Walbaum, 1792). It was introduced in BiH for the first time in 1894, stocked some of our salmonid rivers (Korjenić, 2010). It is raised in concrete and cage ponds, which are two different biological environments in terms of the physicochemical properties of water. Under conditions of intensive farming, rainbow trout grows at a faster pace; it is extremely adaptable to the living environment and is significantly more resistant to parasitic and bacterial diseases relative to other species that reproduce and grow under artificial conditions. Also, its nutritional quality is excellent (Davies & Bromage, 2002; Davidson et al., 2011; Vranić et al., 2011). A right choice of parental material under intensive breeding conditions ensures high production parameters of the rainbow trout offspring (Vehviläinen et al., 2012). Intensive production of this fish species requires several factors that should allow the most favorable conditions for life and a fast growth of fish population, i.e. to contribute to a faster achievement of the planned production and placement of the final product on the market. The previous studies have shown that photoperiod, temperature and amount of dissolved oxygen i.e. their values during spawning significantly affect the production in aquaculture (Randall, 2001; Pornsoping et al., 2007; Jažić et al., 2011). Technology of breeding rainbow trout must provide elementary conditions: clean water that fulfills the oxygen requirement (9-11mg/l), an appropriate water temperature (8-12°C), pH of water (6,5-8,5) and a sufficient flow of water and a systematic diet with different types of industrial and natural feeds (Ćuk et al., 2006; Marković et al., 2006; McMillan et al., 2012). In artificial breeding of rainbow trout, diet is without any doubt the most difficult and complex undertaking. Complexity of the problem with diet comes not so much from the type and amount of feed, but more from the fact that it is

conditioned by a range of different factors. A high productivity is based on a balanced and proper diet with all components that support intensive growth and prevent diseases (Klontz, 1991; Willoughby, 1999; Akbary et al., 2010).

Interesting biology and extreme economic significance of rainbow trout are the reasons behind intensive studies of many authors from our region (Mikavica et al., 2005; Muhamedagić et al., 2010; Savić et al., 2013b). These authors mainly examined the growth (length and weight) of rainbow trout relative to diet or different conditions of habitat (Pelo et al., 2012). In addition, the studies of the health of salmonids, the quality and nutritional values of meat, a significance in human diet and monitoring of morphometric and hematological indexes were carried out (Jeremić et al., 2003; Baltić et al., 2009; Jažić et al., 2011; Vranić et al., 2011).

Starting with an assumption that production and economic performance of salmonid species are affected significantly by artificial breeding, the goal of this study was to compare the growth, gonadosomatic index (GSI) and histological properties of the testicles in rainbow trout fed with pellet feed manufactured by two manufacturers, Coppens and Skretting.

2. Material and Methods

The studies monitored two groups of 30 rainbow trout males. The age of the specimen was determined on the basis of fish scales. Sampling of the rainbow trout males was carried out at two fish farms: Royal fish and Magazin Maprim. The Royal fish farm is located at Grabovica lake (lat: 43.626; lon: 17.751), hydroaccumulation of Neretva River, with intensive breeding in the floating cages. The Magazin Maprim fish farm with a classic intensive fish farming in concrete ponds is located at Ramički creek (lat: 43.89; 18.131), which flows into Bosna River (Figure 1.).

Figure 1. Geographic distribution of investigated fish farms in B&H

Pellet fish feed manufactured by Coppens (Holland) was used at the Magazin Maprim fish farm, while Skretting (Italy) feed was used at the Royal fish farm. Fish were fed twice daily on a 5 % body weight basis.
The measurements carried out at the fish farms included the basic physicochemical parameters of the quality of water (temperature, concentration of dissolved oxygen and pH values) and were done using a measurement device Multi 340i/SET (Germany).

2.1. Morphometric parameters and gonadosomatic index (GSI)

Sampled fish males were measured for the following morphometric parameters: total body length, total body weight and testicular weight. Total body length is a total length of a body, from head to the end of the tail. This parameter was measured using ichtiometer. Body weight of the males and the testicular weight were determined using a digital analytical scale (Tehtnica ET 1111) with a precision of two decimals, at the Histology Laboratory of the Faculty of Science Sarajevo. The data collected was used to calculate the gonadosomatic index (GSI) using the formula (Bolger & Connolly, 1989):

$$GSI = \text{gonad weight (g)}/\text{total fish weight (g)}*100$$

2.2. Histological analysis of the testicles

For the histological examination, after the separation from the surrounding tissues, the testicles were fixated in 10% formaldehyde. Microscopic preparations were made and analyzed in the Histology and Embryology Laboratory of the Veterinary Faculty in Sarajevo. Sample processing, from fixation to molding with paraffinn, was carried out on a rotational tissue processor (MICROM model STP 120). After molding, the samples were cut using digital microtome (LEICA RM 2145), several serial cuts from 0,5 to 1,5 micrometer thick and stained with standard method of hematoxylin-eosin (Bancroft & Cook, 1994). Examination of the histological preparations was done using a light microscope equipped with camera MOTIC TYPE 102M, under magnification of 100, 200 and 400x. The analyses of histological structures were carried out using a special program Motic Images Plus 2.0 ML.

2.3. Statistical analysis

Obtained results of measurement were statistically analysed using software Statistica 8.0 (©Copyright StatSoft, Inc. 1984-2007). The results of the morphometric measurements were presented as arithmetic means of measurements with a

standard deviation accompanied by minimum, maximum and coefficient of variation (%), (Microsoft Excel, 2007). *One way* ANOVA was applied to compare the observed parameters, after which a post-hoc Newman Keuls test followed. Linear regression analysis was used for modelling relationship between gonadosomatic index (GSI), total length, body weight and testicular weight. The analyses applied the level of a statistical significance of $P < 0.05$.

3. Results

3.1. Composition of pelleted fish feed and the parameters of the quality of water

Values of nutrients in pelleted fish feed was used in the diet of rainbow trout at the examined fish farms, are presented in (Table 1.). The table shows that fish foods are approximately similar in composition.

Table 1. Comparative illustration of pelleted fish feed composition

Manufactured	Pelleted fish feed	Crude protein (%)	Crude fat (%)	Crude fibre (%)	Ash (%)	Phosphorus (%)	Vitamin A IU/kg	Vitamin D3 IU/kg
Skreting (Italy)	Skreting optiline HE 2P	42	26	3	4,0	0,6	5000	1 000
Cooppens (Holland)	Ultra troco	43	28	1	8,3	0,9	15 000	3 000

The measured values of physicochemical parameters of water at the examined fish farms were within acceptable values for the rainbow trout breeding (Table 2.).

Table 2. Values of physicochemical parameters of water at the examined fish farms

Fish farm	Magazin Maprim	Royal fish
Temperture	11 °C	8 °C
Concentration of dissolved oxygen	10 mg/l	9 mg/l
Water pH	8.3	8.15

3.2. Morphometric parameters and gonadosomatic index (GSI)

Descriptive statistics of the morphometric parameters, weight testicular and gonadosomatic index is presented in (Table 3.). Our results show that the average values of a total length (34.80±1.86 cm) and a total body weight (563±53 g) of the males from the Royal fish farm fed with Skretting feed differ significantly from the values of a total length (26.70±2.05 cm) and a total body weight (237±62.46 g) of the males from the Magazine Maprim fish farm that used Coppens feed. The average testicular weight (13.56±4.18 g) of the males fed with Skretting feed did not show any significant difference as compared to the testicular weight (8.38±3.96 g) of the

males fed with Coppens feed. The gonadosomatic index (2,39±0,58) of the males from the Royal fish farm did not differ statistically from the gonadosomatic index (3,47±1,06) values of the males from the Magazin Maprim fish farm.

Table 3. Total length, body weight, weight testicular and gonadosomatic index of rainbow trout in fish farms

Fish farm	Statistical parameter	Total length (cm)	Body weight	Testicular weight	Gonadosomatic index
Floating cages ponds	Mean	34.80*	562.80*	13.56	2.39
	Standard deviation	1.86	53.31	4.18	0.58
	Minimum	31.50	476.00	9.63	2.02
	Maximum	36.00	609.00	20.64	3.42
	Coefficient of variation - %	5.34	9.47	30.83	24.32
Concrete ponds	Mean	26.70*	237.00*	8.38	3.47
	Standard deviation	2.05	62.46	3.96	1.06
	Minimum	24.50	159.00	4.09	2.23
	Maximum	28.50	304.00	14.37	4.73
	Coefficient of variation - %	7.68	26.36	47.23	30.43

Asterisk in superscript denotes significantly different mean values between groups (* P ≤0.05); P - values obtained by Newman Keuls test

3.3. Relationship between the gonadosomatic index (GSI) and body parameters of *Oncorhynchus mykiss*

The gonadosomatic index (GSI) of male *Oncorhynchus mykiss* fed Skretting feed showed a linear relationship with the total length (cm), total weight (g) and testicular weight (g). Power regression equation for the gonadosomatic index (GSI) and total length (cm), total weight (g) and testicular weight (g) of male *Oncorhynchus mykiss* fed Skretting feed is as follows:

$$GSI=0.0987\times-1.0482 \ (r^2=0.0998, P>0.05)$$
$$GSI=0.0057\times-0.8156 \ (r^2=0.2731, P>0.05)$$
$$GSI=0.1355\times-0.5494 \ (r^2=0.952, P>0.05)$$

The gonadosomatic index (GSI) of male *Oncorhynchus mykiss* fed Coppens feed showed a linear relationship with the total length (cm), total weight (g) and testicular weight (g). Power regression equation for the gonadosomatic index (GSI) and total length (cm), total weight (g) and testicular weight (g) of male *Oncorhynchus mykiss* fed Coppens feed is as follows:

$$GSI=0.1986\times-1.8316 \ (r^2=0.1485, P>0.05)$$
$$GSI=0.005\times-2.2856 \ (r^2=0.0875, P>0.05)$$
$$GSI=0.2155\times-1.6649 \ (r^2=0.6525, P>0.05)$$

3.4. Histological analysis of testicles of rainbow trout

Histological changes of the testicles during the maturation were similar in both examined groups. Interstitial tissue was well developed while the lobules were clearly separated. Tunica was very thin (Figure 2.). All stages of spermatogenesis classified as spermatocytogenesis, meiosis and spermiogenesis as well as the cells that belong to the respective stages were clearly visible in the semen tubes (Figure 3.). There were also slight differences in a degree of the testicular maturation between the observed groups, and they are related to the spermiogenesis process that progressed in the semen tubes of the testicles of rainbow trout fished at the Royal fish farm.

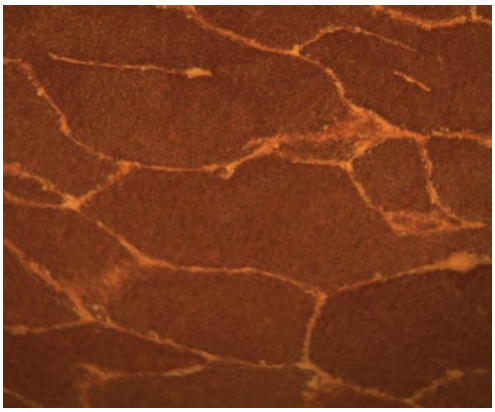

Figure 2. Lobularity: expressed testicular parenchyma (HE×200)

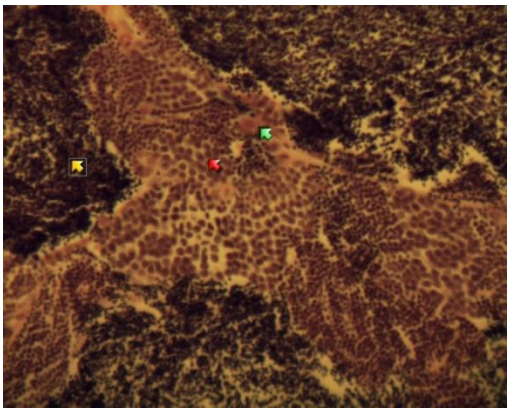

Figure 3. Spermatogenesis: green arrow - spermatogonia A; red arrow - spermatogonia B; yellow arrow - sperms (HE×400)

4. Discussion

Over the course of the previous period, the market in FBiH offered pellet fish feed of various manufactures with significant oscillations in terms of the percentage of raw materials in their composition. To assess the quality of the fish feed, besides the data on its chemical composition, the main criteria is a growth pace. Rainbow trout has one significant peculiarity that achieves a high biomass growth in a short span of time. Nutritional values of meat and reaching high values of biomass are sufficient reasons why rainbow trout has become one of dominant species at the world fish meat market. A growth of rainbow trout i.e. a pace of the length and weight growth in differing abiotic factors of the breeding environment and application of different feeds was the subject of many studies (Uysal, 2002; Guzel & Arvas, 2011; Kizak et al., 2011; Pelo et al., 2012; Sevgili et al., 2012; Savić et al., 2013a).

Based on the data on the growth pace of rainbow trout fed with pellet feed of various manufacturers, it was concluded that the examined types of the feed contained all

optimal values of nutritive materials necessary for the growth, and the growth pace depended on the variations of physicochemical parameters of water.

Pelo et al. (2012) has showed that the composition of the feed and a number of feedings during the day play a key role in a growth of biomass of rainbow trout raised in a cage pond at water temperature between 7°C and 9°C and that growth of rainbow trout depends on small variations of physicochemical properties of water. The most intensive growth rainbow trout achieved at constant water temperature while significant temperature variations did not have a favorable impact on the biomass production. Similar results were achieved in the study by Ekanem et al. (2012). This group of authors came to a conclusion that various kinds of feed tested under the same physicochemical parameters of water lead to different mass growth, as a consequence of a different share of feed ingredients. Monitoring the impact of Unical Aqua feed and commercial feed manufactured by Coppens on body mass growth, gonadosomatic index (GSI) and morphology of gonads of African catfish, C. gariepinus, was carried out by Eyo et al. (2014). Based on their findings, the examined kinds of feed were quite alike in terms of their performance; only in terms of availability, Unical Aqua feed was more cost effective, which is why it is recommended to fish breeders. However, there was a significantly positive correlation among GSI index, gonads weight, total body length and total body weight in fish fed with both feeds, within physiological values of physicochemical parameters of water. The results of these authors are quite similar to the results of our study. The study that aimed to analyze the impact of the meal size on the growth of rainbow trout progeny (*Oncorhynchus mykiss*) was carried out by Savić et al. (2013). An increase in a meal size by 10% above the recommended values does not lead to any significant differences, but in in case this increase is above 10% statistically significant differences will appear in the body mass. Increasing the daily diet norms for rainbow trout should be in line with their genetic growth potential and conditions of the living environment.

The studies showed that environmental factors such as water temperature, photoperiod, amount of dissolved oxygen and pH values of water significantly affect the intensity of gametogenesis (Campbell et al., 1994; Contreras-Sinchez et al., 1998). Their value at times of spawning is extremely important for productive aquaculture (Bromage & Roberts, 1995). Pavlov et al. (2013) cite that the differences in the structure of reproductive system of rainbow trout can be attributed to hormonal effects and abiotic environmental conditions. The intensity of spermatogenesis in rainbow and brown trout, sampled at different locations, was the subject of the examination carried out by Mlaćo et al. (2014). Some significant microstructural differences were identified in the structure of the testicles as well as

in the intensity of spermatogenesis, which indicates that microclimate environment conditions and diet are important factors impacting the reproduction of salmonids. Based on the results of our study, we can agree with the claims of the previous studies. Hiro & Yamamoto (1987) noticed a significant increase of the number of mature sperm cells in Oncorhynchus keta during migration, which indicates that a gametes will mature faster in a colder water. This fact can explain a advanced process of spermiogenesis at the Royal fish farm (water temperature 8°C) as opposed to the Magazin Maprim fish farm (water temperature 11°C). In addition to water temperature and the type of feed, the fish farms used different types of breeding. Higher weight growth was recorded at the Royal fish farm with cage breeding compared to Magazin Maprim with concrete pond breeding. Our results are consistent with the literature data (Mikavica et al., 2005; Ćuk et al., 2006; Pelo et al., 2012; Pilić et al., 2018).

5. Conclusions

This study has shown that there are statistically significant differences in the growth of rainbow trout (*Oncorhynchus mykiss*) in favor of Skretting manufacturer. The values of gonadosomatic index (GSI) and the weight of the testicles along with histological properties of the testicles did not show any significant differences between the observed groups. In line with the results, we believe that choosing the right feed decreases the breeding period, increases productivity and has a positive impact on the fish health and the quality of meat.

6. References

1. Agency for Statistics of the Bosnia and Herzegovina (2012). Aquaculture. Published and printed by the Agency for Statistics of the Bosnia and Herzegovina. First release.
2. Akbary, P., Hosseini, S. A., Imanpoor, M., Sudagar, M., & Makhdomi, N. M. (2010). Comparison between live food and artificial diet on survival rate, growth and body chemical composition of *Oncorhynchus mykiss* larvae. Iranian Journal of Fisheries Sciences, 9 (1), 19-32.
3. Baltić, M., Kilibarda, N., Dimitrijević, M., & Karabasil, N. (2009). Meso ribe–značaj i potrošnja. IV međunarodna konferencija „Ribarstvo“ 27-29. maj. Poljoprivredni fakultet Beograd. Zbornik predavanja, pp. 280-287.
4. Bancroft, J. D. & Cook, H. C. (1994). Manual of histopathological techniques and their diagnostic application. Churchill Livingstone, London. 305pp.

5. Bolger, J. & Connolly, P. L. (1989). The selection of suitable indices for the measurement and analysis of fish condition. Journal of Fish Biology, 34, 171-182.
6. Bromage, N. R. & Roberts, R. J. (1995). Broodstock Management and Egg and Larval Quality. Osmead, Oxford, UK: Blackwell Science, 25-52.
7. Campbell, P. M., Pottinger, T. G., & Sumpter, J. P. (1994). Preliminary evidence that chronic confinement stress reduces the quality of gametes produced by brown and rainbow trout. Aquaculture, 120, 151-169.
8. Contreras-Sinchez, W. M., Schreck, C. B., Fitzpatrick, M. S., & Pereira, C. B. (1998). Effects of Stress on the Reproductive Performance of Rainbow Trout (Oncorhynchus mykiss). Biology of reproduction, 58, 439-447.
9. Ćuk, D., Marković, Z., & Grubić, G. (2006). Uticaj različitog sadržaja masti u dve smeše koncentrata na prirast kalifornijske pastrmke (Oncorhynchus mykiss Walbaum, 1792) u kaveznom sistemu gajenja. Biotechnology in animal husbandry, 22, 351-358.
10. Davidson, J., Good, C., Welsh, C., & Summerfelt, S. (2011). The effects of ozone and water exchange rates on water quality and rainbow trout Oncorhynchus mykiss performance in replicated water recirculating systems. Aquacultural Engineering, 44, 80-96.
11. Davies, B. & Bromage, N. (2002). The effects of fluctuating seasonal and constant water temperatures on the photoperiodic advancement of reproduction in female rainbow trout, Oncorhynchus mykiss. Aquaculture, 205, 183-200.
12. Ekanem, A. P., Eyo, V. O., Obiekezie, A. I., Enin Udeme, I., & Udo, P. J. (2012). A Comparative Study of the Growth Performance and Food Utilisation of the African Catfsh (Clarias gariepinus) Fed Unical Aqua Feed and Coppens Commercial Feed. Journal of Marine Biology & Oceanography, 1(2), 1-6.
13. Eyo, V. O., Ekanem, A. P., & Ufonima Udo, J. (2014). A comparative study of the gonado-somatic index (GSI) and gonad gross morphology of african catfish (Clarias gariepinus) fed Unical Aqua feed and Coppens Commercial feed. Croatian Journal of Fisheries, 72, 63-69.
14. Guzel, S. & Arvas, A. (2011). Effects of different feeding strategies on the growth of young rainbow trout (Oncorhynchus mykiss). African Journal of Biotechnology, 10(25), 5048-5052.
15. Hiro, O. & Yamamoto, K. (1987). Studies on the maturation of salmonid fishes changes in the testis of the chum salmon, Oncorhynchus keta, during anadromous migration. Bulletin of the faculty of fisheries Hokkaido University, 19(3), 73-187.
16. Jažić, A., Balić, S., Duhovnik, J., Zuko, A., & Omeragić, J. (2011). Istraživanje sistema za obogaćivanje vode kiseonikom na ribljim farmama. Veterinaria, 60(3-4), 127-140.

17. Jeremić, S. (2003). Aktuelne bolesti kalifornijske pastrmke i šarana izazvane abiotičkim faktorima. Zbornik predavanja Seminara „Pastrmsko i šaransko ribarstvo", p. 85-91.
18. Kizak, V., Guner, Y., Turel, M., Can, E., & Kazim, M. (2011). Comparison of the survival and growth performance in rainbow trout (Oncorhynchus mykiss) and brown trout (Salmo trutta fario) fry. African Journal of Agricultural Research, 6(25), 5672-5674.
19. Klontz, G. W. (1991). Manual for raunbow trout production on the family-owned farm. Department of fish and Wildlife Resources University of Idalo. Moscow, Idalo.
20. Korjenić, E. (2010). Salmonikultura. Prirodno-matematički fakultet Univerziteta u Sarajevu. 77pp.
21. Marković, Z., Poleksić, V., & Dulić, Z. (2006). Optimalna koncentracija kiseonika u vodi pastrmskih ribnjaka-preduslov dobre proizvodnje. Biotehnologija u stočarstvu, 22, 103-112.
22. McMillan, J. R., Dunham, J. B., Reeves, G. H., Mills, J. S., & Jordan, C. E. (2012). Individual condition and stream temperature influence early maturation of rainbow and steelhead trout, Oncorhynchus mykiss. Environmental Biology of Fish, 93, 343-355.
23. Mikavica, D., Savić, N., & Vuković, D. (2005). Biotehnologija uzgoja dužičaste pastrmke (Oncorhynchus mykiss Wal.) u kavezima na ekološki podesnim lokalitetima hidrografskog područja u Bosni i Hercegovini. Zbornik sažetaka "Agrar na pragu trećeg milenija", Neum, p. 12.
24. Mlaćo, N., Katica, A., & Pilić, S. (2014). Comparative histology of testes of brown (Salmo trutta m. fario) and california (Oncorhynchus mykiss) trout during the spawning period. Biotechnology in Animal Husbandry, 30(3), 489-497.
25. Muhamedagić, S., Hamzić, A., Vegara, M., Pavličević, J., & Ćindrak, M. (2010). Poboljšanje proizvodnje u uzgoju komercijalnih i autohtonih vrsta riba u salmonidnoj akvakulturi Federacije BiH. 1st Interntional symposium of fisheries and fishing tourism. Centar za ribarstvo „Neretva" Konjic, Boračko jezero, Bosna i Hercegovina, p. 77-86.
26. Pavlov, E. D., Ganzha, E. V., Tui, N. V., & Tu, N. T. H. (2013). State of Gonads of Yearlings of Triploid Rainbow Trout Oncorhynchus mykiss Exposed to Androgenic Hormone under High Mountain Conditions of South Vietnam. Journal of Ichthyology, 53(9), 739-752.
27. Pelo, A., Zujo-Zekić, D., & Adrović, A. (2012). Preliminary results length and weight growth rates of species Oncorhynchus mykiss (Walbaum, 1792) (Salmoniformes, Salmonidae) on the pond "NORFISH" in Blagaj. Third International Scientific Symposium "Agrosym 2012", 15-17 november, Jahorina,

Bosnia and Herzegovina, Faculty of Agriculture, University of East Sarajevo. p. 356-362.
28. Pilić, S., Mlaćo, N., Katica, A., Katica, V., Mujezinović, I., & Katica, J. (2018). Histological characteristic features of the rainbow trout Oncorhynchus mykiss ovaries (Walbaum, 1792) grown in various microambient conditions. Veterinary Journal of Republic of Srpska (Banja Luka), XVIII (2), 326-341.
29. Pornsoping, P., Unsrisong, G., Vearasilp, T., Wessels, S., & Hörstgen-Schwark, G. (2007). Reproductive performance of female rainbow trout Oncorhynchus mykiss (Walbaum) kept under water temperature and photoperiods of 13° and 51° N latitude. Aquaculture Research, 38, 1265-1273.
30. Randall, C. (2001). Photoperiod effects on reproduction and growth in rainbow trout. Trout News, 32, 12-16.
31. Savić, N. M., Drinić, M. S., Važić, B. S., & Rogić, B. S. (2013a). Uticaj različite veličine obroka na karakteristike rasta mlađi dužičaste pastrmke (Oncorhynchus mykiss Wal.). Journal of Agricultural Sciences, 58(3), 185-193.
32. Savić, N., Mikavica, D., & Rogić, B. (2013b). The growth characteristics of rainbow trout fry (Oncorhynchus mykiss Wal.) from different localities. II International symposium and XVIII Scientific Conference of Agronomists of Republic of Srpska, Trebinje, p. 157.
33. Sevgili, H., Hoşsu, B., Emre, Y., & Kanyılmaz, M. (2012). Compensatory growth after various levels of dietary protein restriction in rainbow trout, Oncorhynchus mykiss. Aquaculture, 126-134.
34. Uysal, I. & Alpbaz, A. (2002). Comparison of the growth performance and mortality in abant trout (Salmo trutta abanticus Tortonese, 1954) and rainbow trout (Oncorhynchus mykiss Walbaum, 1792) under farming conditions. Turkish Journal of Zoology, 26, 399-403.
35. Vehviläinen, H., Kause, A., Kuukka-Antilla, H., Koskinen, H., & Paananen, T. (2012). Untangling the positive genetic correlation between rainbow trout growth and survival. Evolutionary Applications, 5(7), 732-745.
36. Vranić, D., Đinović-Stojanović, J., & Spirić A. (2011). Kalifornijska pastrmka (Oncorhynchus mykiss) iz akvakulture-kvalitet mesa i značaj u ishrani. Tehnologija mesa, 52(1), 122-133.
37. Willoughby, S. (1999). Manual of Salmonids Farming. Fishing new books. Blackwell Science.

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8. Authors Contribution

The authors confirm their contribution to the paper as follows: study conception and design: Selma Pilić, Anesa Jerković-Mujkić, Amela Katica, Nadžida Mlaćo; data collection: Selma Pilić, Enad Korjenić, Aldijana Mušović; analysis and interpretation of results: Selma Pilić, Adi Vesnić, Mahir Gajević: draft manuscript preparation: Selma Pilić, Anesa Jerković-Mujkić, Amela Katica, Nadžida Mlaćo, Enad Korjenić, Adi Vesnić, Aldijana Mušović, Mahir Gajević. All authors reviewed the results and approved the final version of the manuscript.

9. Conflict of Interest Statement

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Research on Climate Change Knowledge among Students of the Department of Biology

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Abstract

Climate change is a term used to describe changes in overall weather patterns and an increase in global temperatures worldwide. The phenomenon of climate change is one of the biggest problems facing the majority of the world's population. Today, the popularization of this topic is more and more expressed in non-scientific circles (media), which requires a multidimensional approach in measuring knowledge about the mentioned topic at the academic level. This research gives us an insight into the knowledge of the students of the Department of Biology at the Faculty of Science in Sarajevo about the causes, consequences, and measures to mitigate the negative effects of climate change. In the academic year 2022/2023, a total of 45 respondents filled out the survey, which for practical reasons was divided into six cognitive levels. Descriptive statistics and multiple regression analysis were used for data analysis. The research showed that biology students are familiar with the basic processes associated with climate change (especially younger students). Also, the respondents are aware of the consequences of climate change and can relate them to the causes. As for mitigation knowledge, students are familiar with measures to mitigate the consequences of climate change but are uninformed about climate-friendly activities. Multiple regression analysis indicated the existence of a statistically significant difference in the knowledge of the respondents. In our case, students of

lower years of study and younger age showed better procedural knowledge than older colleagues. With regards to influence of gender on the respondents' knowledge, women are more familiar with the causes of climate change than men.

Keywords: climate change knowledge, biology students, education.

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1. Introduction

Climate change refers to a change in overall weather phenomena and an increase in global temperatures. It is generally understood as a long-term change in average weather patterns around the world. The expansion of the industrial production at the end of the 19th century led to an increase in the concentration of greenhouse gases (CFC12, HCFC22, SF6, CH4) in the atmosphere, which was the first sign of anthropogenic influence on the climate (Dhal, 2021). Most of the Sun's radiation (about 70%) is reflected, and greenhouse gases absorb it and thus heat the atmosphere. This means that the increased concentration of greenhouse gases in the atmosphere (especially CO_2) causes an increase in air temperature on a global level (Dakić, 2020). Human activity contributes to greenhouse gas emissions through the transformation of chemical energy from fossil fuels into different types of energy-usable resources (electricity, heat and cold). Natural sources contribute to adverse emissions through changes in nature that include: water vapor, volcanic eruptions and biomass decay, and biological processes in the oceans (Perić & Šverko-Grdić, 2017). According to the Intergovernmental Panel on Climate Change (IPCC), it is estimated that Bosnia and Herzegovina will be affected by global warming with an average temperature increase of 0.7°C-1.6°C. The general trend in B&H shows an average increase in temperature and an average decrease in precipitation volume, which results in drier summers and reduced precipitation volume during winter. A surplus in the amount of rainfall was recorded in the last decade in the central mountain zone, while a deficit in the amount of precipitation was registered in the southwestern parts of the country (Knežević & Suljić, 2012). The lack of snow cover in the winter period causes a disturbance in the ecological factors of the subalpine and alpine belt, which leads to a change in the habitat and ecological niches of plants and animals (Barudanović et al., 2015). An extreme drought was recorded in 2012 in the territory of Herzegovina, while strong floods in May 2014 threatened the existence of numerous towns in the local area. All the above had a very negative impact on agriculture and the supply of food to the population (Čustović et al., 2015).

There is very little interest in climate change research in B&H. Nevertheless, the impact of climate change on public health and complete ecosystems is often the subject of debate in scientific and non-scientific circles- media (Jug, 2016). This research provides an insight into the knowledge of climate change phenomena among students of the Department of Biology at Faculty of Science Sarajevo.

1.1. Dimensioning knowledge about climate change - trend or need?

Learning how to live with climate change represents an ontological-existential problem, for the solution of which it is necessary to apply a special pedagogical approach to teaching (Verlie, 2019). For this reason, a completely new scientific subdiscipline - climate change pedagogy has developed as part of conventional pedagogy. The task of climate change pedagogy is to shape the individual's personality in such a way as to understand the causes, consequences, and the role of man in the occurrence of climate change. Applying climate change pedagogy means encouraging people to adopt an ecocentric attitude towards nature and its resources (Hadžiselimović, 2015). This implies the application of certain socially and professionally acceptable procedures, which will have a favorable effect on the climate of an area. Some of these practices include: waste disposal according to regulations, reducing the use of fossil fuels, preserving wetlands, climate-friendly actions such as reforestation (Bašić, 2001).

Knowledge about climate change can be acquired through formal education (higher education institutions and schools), and through the influence of certain informal outlets of information such as media, museums visits, bookstores and zoos. Considering the increasingly evident consequences of climate change, the need for a new type of literacy has arisen, namely climate literacy (Miléř & Sládek, 2011). Climate literacy is part of the United Nation’s program for Sustainable Development, which serves as a "tool" for climate literacy of students of natural and related science profiles. This program integrates four thematic frameworks for Education about Sustainable Development: a) Science and knowledge about climate, b) Education about climate change, c) Climate change, cultural and biological diversity, and preservation of cultural heritage, and d) Ethical and social aspects of climate change (Reimers, 2021). According to previous research, the most comprehensive concept for measuring climate change knowledge was applied in the survey (Taddicken et al., 2018). The original concept represents a five-dimensional approach to the knowledge of climate change phenomena. For practical reasons, the described

concept has been modified with an additional dimension that includes knowledge about readiness for mitigation, which is explained in (Table 1.).

Table 1. A conceptual approach to measuring climate change knowledge

Basic knowledge	It includes some basic scientific knowledge about $C0_2$, the greenhouse effect, and their connection with the occurrence of climate change. It doesn't include knowledge about specific climate models, which makes it acceptable to respondents who are not part of any of the sectors dealing with climate change.
Causal knowledge	It refers to knowing the most common causes of climate change. For this level of knowledge, the respondent should distinguish the causes and consequences of climate change and be aware that climate change is mostly caused by the irresponsible attitude of human towards nature.
Effects knowledge	A specific level of knowledge in which it is desirable that the respondent not only knows the facts about the increase in the global average air temperature, but also needs to understand the consequences that this increase has on an international level. For the respondent to know whether it is possible to expect the same amount of precipitation everywhere in the world (e.g., in the Philippines and in Bosnia and Herzegovina); it is necessary to continue his formal education in an appropriate higher education institution.
Procedural knowledge	The level of knowledge implies that the respondent is aware of the multidisciplinary of climate science. This level of knowledge allows the examinee to understand that the prognostic character of climate science is limited, and that we can't fully rely on just one source to monitor climate models.
Action-related knowledge	This level of knowledge implies understanding which of our actions have a positive/negative effect on the climate (primarily on increasing CO2 concentration), and how to revise them if they are not climate acceptable. 6. Mitigation knowledge. The level of knowledge is designed for the needs of this research. The task of this level of knowledge is to prepare respondents for a responsible professional and social contribution to solving and mitigating the consequences of climate change.
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2. Material and Methods

2.1. Survey and sample

The interest group for researching knowledge about climate change were undergraduate students of the Department of Biology at the Faculty of Science. An online questionnaire was used as a research instrument. The survey contains a total of 50 items, and for the sake of easier data processing, it is divided into two parts. Questionnaire used as a research instrument was created by Tadicken et al. (2018) for similar investigation conducted in Germany. The questions in the general part of the questionnaire were related to the socio-demographic characteristics of the

respondents, namely: year of study, field of study, gender and age of the respondents.

From March to May 2023, a total of 45 students completed the survey. Students of the first year of study (16 respondents) and students of the second year of study (20 respondents) had the greatest interest in participating in the research. The lowest response to the research was among students in the third (five respondents) and fourth year of study (four respondents). The schedule of responses according to socio-demographics is shown in (Table 2.).

Table 2. Socio-demographic structure of the sample

Year of study	Respondents (N)	Frequencies (%)
First year	16	36%
Second year	20	44%
Third year	5	11%
Fourth year	4	9%
Field of study		
Genetics	17	38%
Microbiology	13	29%
Biochemistry and physiology	8	18%
Ecology	5	11%
Teaching major	2	4%
Gender		
Female	39	87%
Male	6	13%
Age		
19-20	27	60%
21-22	15	33%
23	3	7%

The main part of the questionnaire contains a total of 46 items concerning the knowledge of biology students about climate change. In this part of the survey, respondents' knowledge is grouped into six different dimensions, described above (Table 1). The statements in the main part were evaluated by students using a Likert scale, according to the previously established numerical-categorical pattern: 1-Absolutely disagree, 2-Partially disagree, 3-Neutral, 4-Partially agree, 5-Absolutely agree.

2.2. Research hypotheses

Based on data from literature sources, and by analyzing the available theoretical knowledge on this topic, the following hypotheses were set:

1. Biology undergraduate students have basic knowledge about climate change.

2. Students are familiar with the causes of climate change, are aware of its consequences, and have knowledge about the possibilities for mitigating the negative impact of climate change.

3. Students of the first and second year of biology studies show a weaker knowledge of climate change phenomena than students of the third and fourth year.

4. Students of the third and fourth year show a better acquired knowledge about climate change.

2.3. Data analysis

At the beginning we measured the Cronbach's α of the entire questionnaire, as well as individual cognitive dimensions. Cronbach's α for the entire survey was 0.74 which makes this research instrument sufficiently reliable and appropriate for use (Cohen et al., 2007).

All data were analyzed using Microsoft Excel 2013. As the first step in the data analysis, descriptive statistics were applied, and for the purposes of this research, we defined the following individual and overall mean values: 1-1.80-Absolutely disagree; 1.81-2.70-Partially disagree; 2.71-3.40-Neutral; 3.41-4.10-Partially agree; 4.11-5.00- Absolutely agree.

The undergraduate study of biology lasts four years, so the application of exclusively descriptive statistics in the evaluation of students' knowledge is not sufficient. This was the indicator for the application of multiple regression analysis test (with significance level at 0.05), to determine whether differences in level of knowledge can be explained with selected socio-demographics such as: year of study, gender, and respondents' age (Petz, 2007).

3. Results

In the following chapter we present our findings on climate change knowledge among biology students. Descriptive statistics for all cognitive dimensions are presented in (Table 3.).

Table 3. Descriptive statistics for six cognitive dimensions

Cognitive dimension	Overall mean (M)	Overall standard deviation (SD)	Cronbach's α
Basic knowledge	3.41	1.34	0.09
Causal knowledge	3.63	1.26	0.11
Effects knowledge	3.51	1.39	0.31
Procedural knowledge	4.09	0.98	0.76
Action-related knowledge	3.40	1.11	0.43
Mitigation knowledge	4.06	1.14	0.76

3.1. Basic knowledge

Biology students showed very good basic knowledge. Respondents partially agree that CO_2 is a greenhouse gas, and they are completely sure that burning oil increases

its atmospheric concentration. The majority of respondents are familiar with the role of greenhouse gases in retaining the Earth's heat radiation and show a tendency to partially agree with this statement. Students have a pronounced misconception about the connection between ozone holes and the greenhouse effect, so they are sure that statement is correct. The respondents are not sure whether CO_2 is more harmful for the climate than CH4, so they are neutral about this item. As we can see in (Table 3.) all respondents tend to partially agree with all statements. Response frequencies for basic knowledge are available in (Figure 1.).

3.2. Causal knowledge

Our respondents seem to be aware that the concentration of CO_2 has increased in the last 250 years, and that this has led to an increase in the average air temperature. Students are almost certain that climate change cannot be explained by changes in nature, and they are convinced that the human factor has the most influence on the mentioned phenomenon. Most respondents are uninformed that the 1990s were the warmest decade of the last century, and they declare themselves neutral. Overall mean indicates that most respondents partially agreed with all statements. Response frequencies for causal knowledge are shown in (Figure 2.).

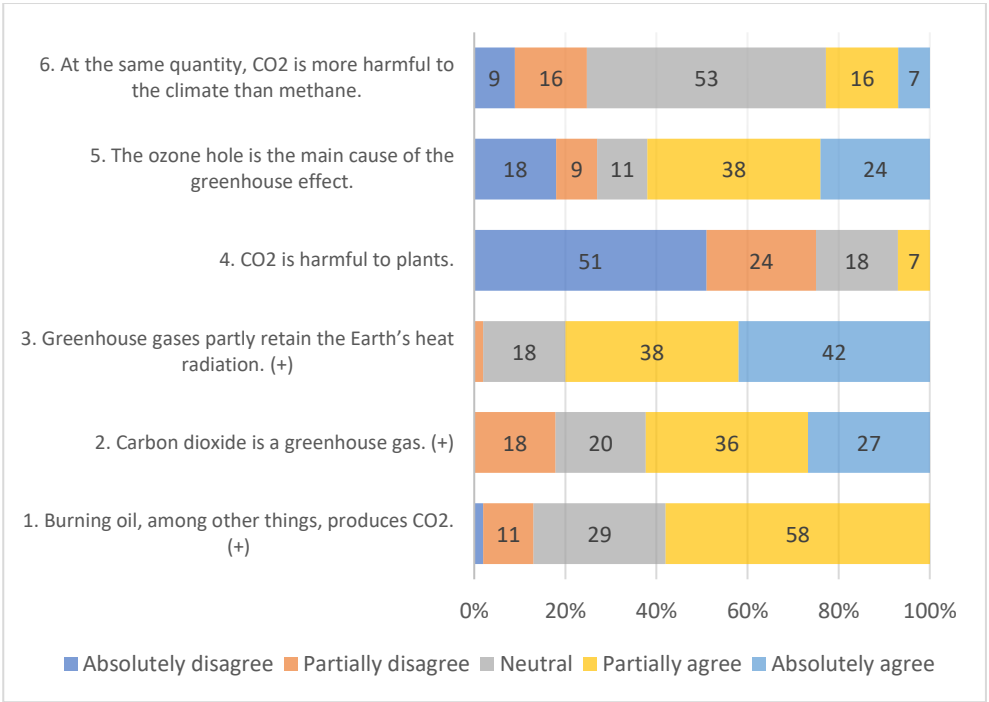

Figure 1. Response frequencies for basic knowledge ((+) - correct statement)

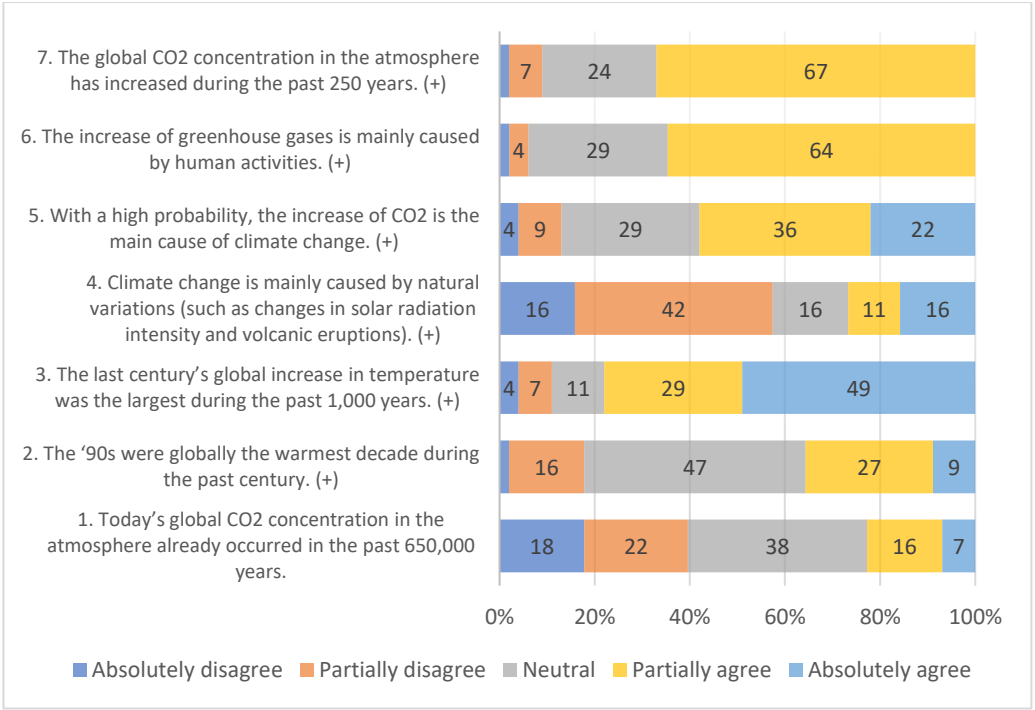

Figure 2. Response frequencies for causal knowledge ((+) - correct statement)

3.3. Effects knowledge

As (Figure 3.) shows, most students absolutely agree with the first two statements about the expected consequences of climate change. Respondents are neutral about whether the climate will cool down in the near future (see item 3), and whether a warmer climate can cause a decrease in sea level (see item 4). Students seem to be aware that the climate cannot change uniformly everywhere in the world, and they show a tendency to partially disagree. It is noticeable that the respondents are not familiar with the fact that we cannot expect an increase in the amount of precipitation everywhere in the world, so they are mostly neutral on this issue. The value of the overall mean indicates that the students have a solid knowledge of the consequences of climate change, with the fact that for more difficult questions they prefer to choose the neutral category, rather than really think about the accuracy of the statement.

3.4. Procedural knowledge

Most respondents show a tendency to absolutely agree with statements: 1, 2, 3, 5, 6 and 8. Students are not sure whether short-term climate science observations can be considered trends, as well as whether current and past climates have an impact

on the quality of climate models and declare themselves neutral (Figure 4.). The value of the overall mean indicates that the students are well informed about almost all statements related to this cognitive dimension.

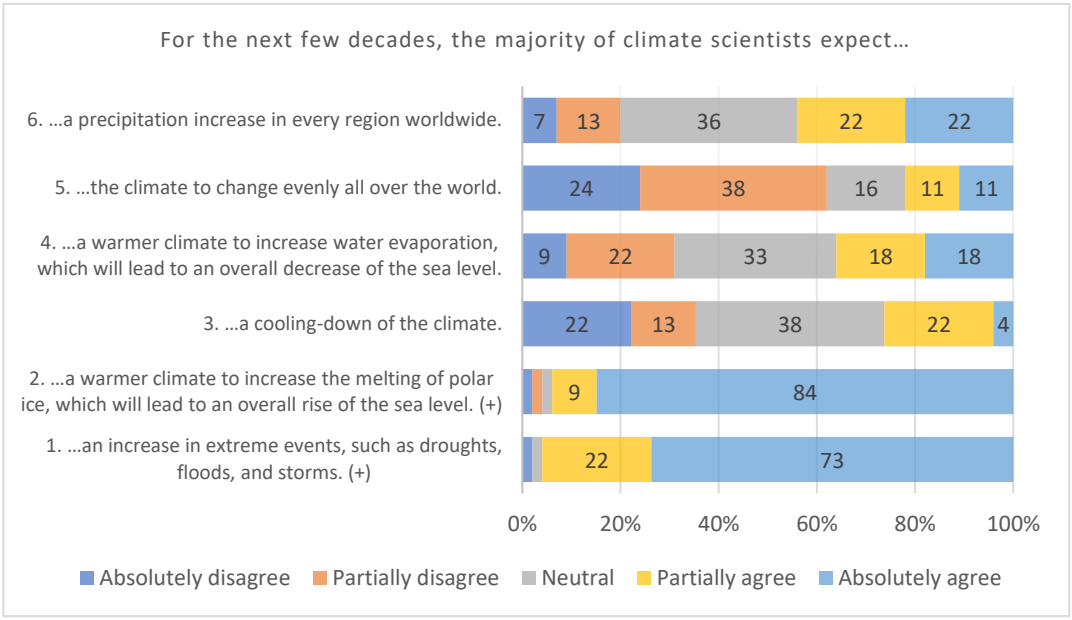

Figure 3. Response frequencies for effects knowledge ((+) - correct statement)

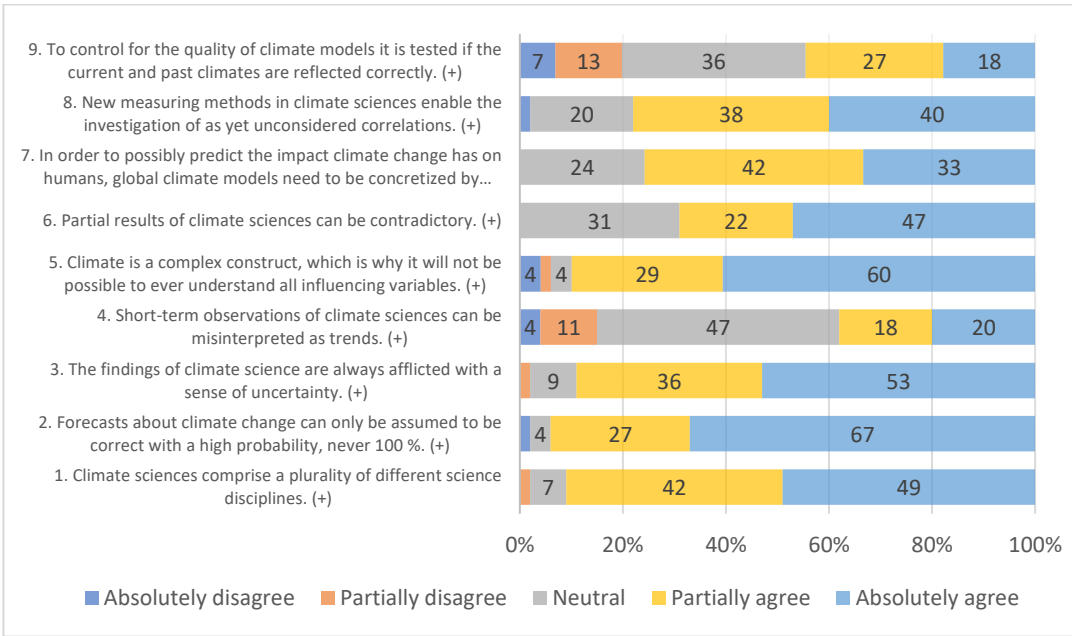

Figure 4. Response frequencies for procedural knowledge ((+) - correct statement)

3.5. Action-related knowledge

In contrast to the German respondents, our respondents are almost completely uninformed about climatically unacceptable activities (see statements 1, 3, 4, 6, 7, 8 and 9). Most students partly agree that the train is a more climate-friendly ways of transport than the car, and that the production of 1 kg of beef causes higher CO_2 emissions than the production of the same amount of wheat. The value of the overall mean indicates that the respondents were extremely uninterested in choosing grades for this level of knowledge and preferred to express themselves neutrally about almost all statements, which is shown in (Figure 5.).

3.6. Mitigation knowledge

Biology students have excellent knowledge about measures to mitigate the consequences of climate change and show a tendency to absolutely agree with almost all statements. The respondents showed a high level of information about energy-efficient ways of organizing private and work activities. As we can see in Figure 6, most students would use fluorescent bulbs instead of conventional ones to light the rooms. Students are also aware of the climate benefit of walking and cycling to go to the workplace. The only thing the students are neutral about is whether instead of turning on the heating, we should wear warm clothes. This was to be expected, given that the claim is partially true. Namely, we must be aware that we cannot fully rely on blankets and clothes when the temperatures are extremely low, so the accuracy of this statement also depends on the individual assessment of the respondents.

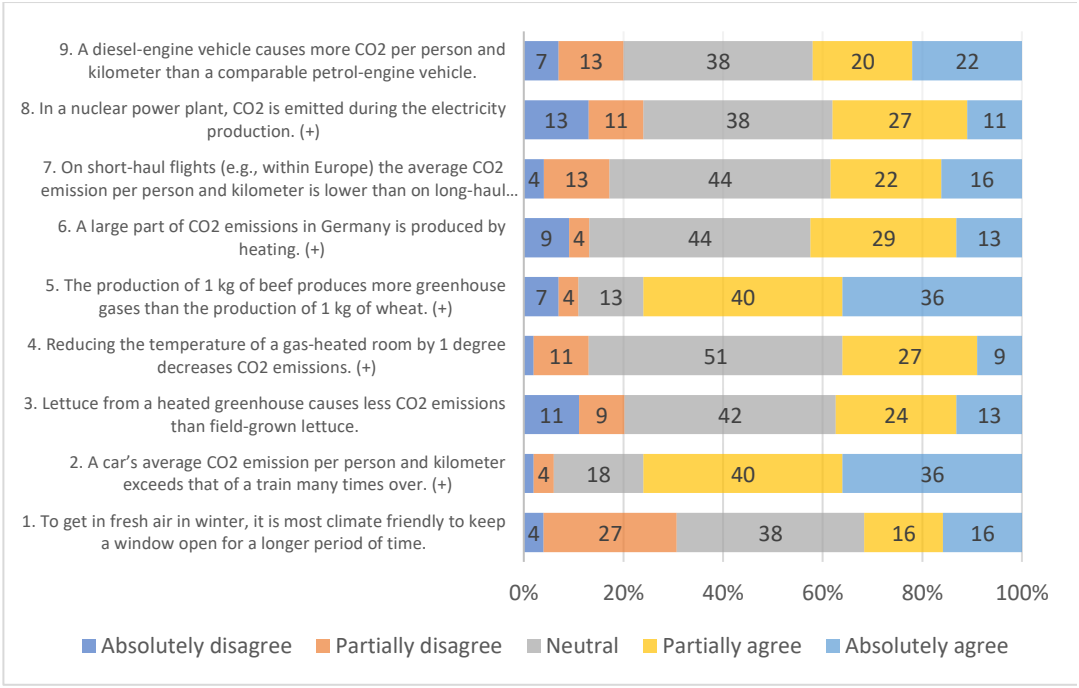

Figure 5. Response frequencies for action-related knowledge ((+) - correct statement)

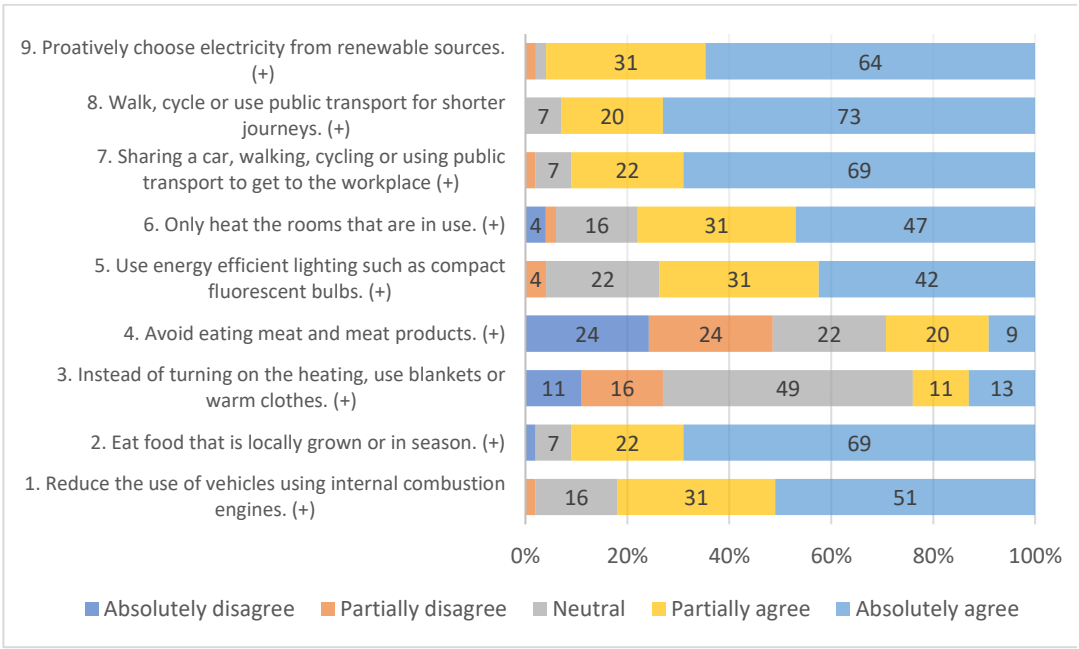

Figure 6. Response frequencies for mitigation knowledge ((+) - correct statement)

3.7. Multiple regression analysis in research on influence of socio-demographic variables on students' knowledge about climate change

Three regression models were included in this research. As we can see in (Table 4.) a total of 26% of the variance in students' knowledge can be attributed to the year of study. If we look at individual coefficients for knowledge levels, we can conclude that only the difference in procedural knowledge can be explained by the year of study ($p=0.01<0.05$). The year of study does not significantly affect other levels of knowledge. The second regression model refers to gender. As shown in (Table 5.), respondents' gender explains a total 23% of the variance in knowledge levels. If we look at the individual coefficients, we can conclude that the only difference in causal knowledge can be explained by gender ($p=0.04<0.05$). In the third regression model (Table 6.), we can see that 31% of the variance in students' knowledge can be explained by age. Individual coefficients make as conclude that only the differences in procedural ($p=0.04<0.05$) and basic knowledge can be explained by the age of the respondents ($p=0.01<0.05$).

Table 4. Multiple regression analysis in researching correlation between students' knowledge about climate change and year of study*

	Coefficients	*P-value*
Year of study*	4.90	0.02
Basic knowledge	0.04	0.46
Causal knowledge	-0.05	0.31
Effects knowledge	-0.01	0.73
Procedural knowledge	-0.05	0.01
Action related knowledge	-0.01	0.68
Mitigation knowledge	0.00	0.97
$R^2 = 0.26$		

*For this regression model we created following dummy variables: 1-First year, 2-Second year, 3-Third year, 4-Fourth year

Table 5. Multiple regression analysis in researching correlation between students' knowledge about climate change and gender*

	Coefficients	P-value
Gender*	1.41	0.05
Basic knowledge	0.001	0.95
Causal knowledge	-0.039	0.04
Effects knowledge	0.013	0.45
Procedural knowledge	0.010	0.61
Action related knowledge	-0.017	0.24
Mitigation knowledge	0.017	0.17
$R^2 = 0.23$		

*For this regression model we created following dummy variables: 1-Male, 2-Female

4. Discussion

The phenomenon of climate change is one of the biggest problems facing most of the the world's population. According to (Umegbolu, 2020), climate change is a problem that started earlier, only today we are becoming aware of its consequences for people and ecosystems. Previous research on climate change phenomena (Tobler et al., 2012) is mainly devoted to the influence of the internet and other means of information on people's knowledge about climate change. Considering very little interest in researching climate change knowledge among biologists, we decided that biology students are appropriate group for this research.

Based on overall mean values from research conducted by (Taddicken et al., 2018), we can see that biology students are similar in knowing basic facts about climate change (Table 3.). Multiple regression analysis showed that only the respondents age affects significantly on basic knowledge, so in this research the younger respondents showed better knowledge (Table 5.).

It seems that biologists showed a little better causal knowledge than the German respondents (Table 3). However, we must notice that our respondents had a certain difficulty answering correctly on statement 4 (Figure 2.). That is the indicator for existing misconception. Multiple regression analysis indicates that only the respondents' gender has an influence on this cognitive dimension (Table 5.) In our sample women are more familiar about causes of climate change than man.

Biology students are mostly aware of the consequences of climate change (Figure 3., Table 3.). Just like Tadicken et al. (2018), they showed difficulties in answering. Most interesting is the fact that students are convinced in accuracy of statement 2, but they are not sure which grade to choose for items 3 and 4. The fact is that if statements 2 is correct, we can't expect a total opposite phenomenon, which is described in statements 3 and 4. Multiple regression analysis showed that selected socio-demographics doesn't significantly affect this cognitive dimension (Tables 4., 5., 6.).

Table 6. Multiple regression analysis in researching correlation between students' knowledge about climate change and age

	Coefficients	*P-value*
Age	18.08	4.64E-11
Basic knowledge	-0.17	0.01
Causal knowledge	0.04	0.45
Effects knowledge	-0.06	0.26
Procedural knowledge	0.12	0.04
Action related knowledge	0.05	0.26
Mitigation knowledge	0.01	0.78
R^2 =0,31		

Based on mean values for our sample, it is noticeable that biologists showed a lot better knowledge about specific climate models than Tadicken et al. (2018) (Figure 4.; Table 3.). Considering the professional orientation of our respondents, that was expected. Multiple regression analysis for this cognitive dimension indicates that the students age and year of study affects significantly on procedural knowledge. According to the age, seems that younger students are more familiar with statements related to procedural knowledge (Table 5.). According to the year of study, first and second year students are the most knowledgeable about facts related to this cognitive dimension (Table 4.).

In contrast to Tadicken et al. (2018), it is noticeable that biologists in our research are uninformed about climate-friendly activities. Most surprising is the fact that students didn't choose grades wisely. Namely, it is impossible for respondents to be neutral about almost all statements (Figure 5.). Multiple regression analysis showed that selected socio-demographics doesn't significantly affect this cognitive dimension (Tables 4., 5., 6.).

Biology students are well informed about mitigation measures we can take to combat the consequences of climate change (Figure 6.). As we can see in (Tables 4., 5., 6.) any of selected socio-demographic variables doesn't significantly affect mitigation knowledge. This cognitive dimension was created for the needs of our research, so the results are very promising. Therefore, we recommend applying this cognitive dimension in further research with the aim of raising awareness about climate change.

Although our article is a good guide for further research on this topic, we must point out its limitations. In contrast to German sample, this research was limited to one academic year, and our respondents were more uninterested to fill the survey. In this case that affected on smaller sample size. Therefore, our Cronbach's α values for all comparable cognitive dimensions are lower than the previous research.

5. Conclusions

Biology students showed very good knowledge about causes, consequences and ways to mitigate negative effects of climate change. However, it is a fact that students of lower years of study are more knowledgeable about some facts related to climate change than their older colleagues. The most challenging for the respondents was to answer correctly to statements related with action-related knowledge, so we can conclude that students were uninformed about climate-acceptable activities. Devastating is the fact that students were neutral about statement 1 (Figure 5.). Respondents should remember that we are living in B&H,

and that we are facing extreme air pollution during winter. Overall mean values for causal and procedural knowledge, indicates that biologists are more knowledgeable on this cognitive dimension than the German respondents. Multiple regression analysis showed that year of study, as well as respondents age significantly affects procedural knowledge. The age of the respondents also affects significantly to basic knowledge. Respondent's gender has a significant effect on causal knowledge. In its original form this research instrument is applicable for further research on climate change knowledge among students of natural and related scientific profiles (e.g., Faculty of Forestry, Faculty of Agriculture). With some adjustments this research instrument can be used in evaluating knowledge of different groups of respondents.

6. References

1. Barudanović, S., Mašić, E. & Macanović, A. (2015). Biodiverzitet i ekosistemski servisi Bosne i Hercegovine. Univerzitet u Sarajevu. Prirodno-matematički fakultet.
2. Bašić, M. (2001). Metodika nastave biologije (1 izd.). Zenica, Dom štampe (pp. 44-48).
3. Cohen, L., Manion, L. & Morrison, K. (2007). Research Methods in Education (6th ed.). Routledge. https://doi.org/10.4324/9780203029053
4. Čustović, H., Ljuša, M. & Sitaula, B. K. (Ur.). (2015). Adaptacija na klimatske promjene u sektoru poljoprivrede-vrijeme je da reagujemo odmah (pp. 97-98). Univerzitet u Sarajevu. Poljoprivredno-prehrambeni fakultet.
5. Dakić, E. (2020). The impact of climate change on water resources in Bosnia and Herzegovina. Electron Collection Papers Faculty Civil Eng 19 (10), 30-38. https://doi.org/10.47960/2232-9080.2020.19.10.30
6. Dhal, P. K. (2021). Education for Climate Change, Environmental Sustainability and World Peace. Social Science Research Network. https://dx.doi.org/10.2139/ssrn.3981679
7. Hadžiselimović, Dž. (2015). Klima se mijenja, a mi… (prilozi psihologiji klimatskih promjena). Pula, Društvo psihologa Istre (pp. 107;173).
8. Jug, D. (2016). Poljoprivreda-dionik kauzalnosti klimatskih promjena. Diacovensia Journal: teološki prilozi 24 (1), 65-79.
9. Knežević, A. & Suljić, V. (2012). Adaptacija klimatskim promjenama u Bosni i Hercegovini. Proceedings No. 22 293-307. https://doi.org/10.5644/proc.bd-01.18
10. Microsoft Corporation (2018). Microsoft Excel. Retrieved from https://office.microsoft.com/excel

11. Miléř, T. & Sládek, P. (2011). International Conference on Education and Educational Psychology (ICEEPSY 2010) The climate literacy challenge. Procedia Social and Behavioral Sciences 12 (2011), 150-156. https://doi.org/10.1016/j.sbspro.2011.02.02
12. Petz, B. (2007). Osnovne statističke metode za nematematičare (7 izd). Jastrebarsko. Naklada Slap. (pp. 237)
13. Perić, J. & Šverko Grdić, Z. (2017). Klimatske promjene i turizam. Sveučilište u Rijeci. Fakultet za menadžment u turizmu i ugostiteljstvu.
14. Reimers, F. M. (2021). The role of Universities Building an Ecosystem of Climate Change Education. In: Reimers F., M., (Ed.). Education and Climate change pp. 3-14. Massachusetts: Harvard University. https://doi.org/10.1007/978-3-030-57927-2
15. Taddicken, M., Hoppe, I. & Reif, A. (2018). What do people know about climate change-and how confident are they? On Measurements and analyses of science related knowledge. Journal of Science Communication 17 (03) (2018) (A01), 1-26. https://doi.org/10.22323/2.17030201
16. Tobler, C., Visschers, V. H. M. & Siegrist, M. (2012). 'Consumers' knowledge about climate change'. Climatic Change 114 (2), pp. 189–209. https://doi.org/10.1007/s10584-011-0393-1.
17. Umegbolu, E. (2020). Awarness and Knowledge of Health Implications of Climate Change in Oji River Lga of Enugu State, Southeast Nigeria. European Journal of Pharmaceutical and Medical Research, 7 (7) 204- 210.
18. Verlie, B. (2019). Bearing Worlds: Learning to Live-with Climate Change. Environmental Education Research 25 (5), 751–766. https://doi.org/10.1080/13504622.2019.1637823

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A Review of Bosnia and Herzegovina Medicinal Plants with Promising Antiviral Properties

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Abstract

The study explored the antiviral potential of ethnobotanical plants in Bosnia and Herzegovina, aiming to identify plants with promising antiviral properties and commonly used plant organs and preparations. Three plant families, Lamiaceae, Compositae and Rosaceae showed significant antiviral potential based on the number of species mentioned in the literature. The most studied viruses were herpes simplex virus (HSV), influenza virus (Influenza), and SARS-CoV-2. Tea was the most popular herbal preparation, and aerial parts and leaves were the most frequently used for therapeutic applications. These findings highlight the potential of plants as natural sources of antiviral compounds, paving the way for further research and new therapeutic approaches.

Keywords: ethnobotany, plants, antiviral potential, viruses, plant parts, herbal preparations, Bosnia and Herzegovina.

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1. Introduction

Viral infections present a significant health problem due to the high rate of morbidity and mortality. Numerous viruses, such as human immunodeficiency virus (HIV), hepatitis A, B and C (HAV, HBV and HCV), and influenza virus, have been virulent and life-threatening pathogens for decades.

Viral infections have caused many pandemics throughout world history. The deadliest pandemic, the Spanish flu of 1918, infected around 500 million people worldwide and have killed 20 to 50 million. Other notable pandemics include the Ebola virus, between 2013 and 2016, resulting in 11,323 deaths (Trilla et al., 2008), as well as the Severe Acute Respiratory Syndrome (SARS) in 2003, the Middle East Respiratory Syndrome (MERS) in 2015 (Zumla et al., 2015), and in 2019 Coronavirus (COVID-19) pandemic, which has led to more than 776,471,644 infections and over 7,068,677 deaths (World Health Organization, 2024).

The major portion of diseases that do not have a cure are viral diseases (Choudhary et al., 2024). In recent decades, advanced scientific research has led to the discovery of many synthetic antiviral agents that effectively combat various viral infectious diseases. These synthetic agents have been reported to cause numerous adverse effects and become ineffective against new virus strains over time (Kurokawa et al., 2010). Even though more and more antiviral drugs have been approved in clinic studies, long-term use can easily lead to the emergence of drug resistance and side effects (Zhao et al., 2023). One of the global problems of viral infections is the cost of treatment, and there is a need to develop new strategies that will enable finding affordable and effective antiviral drugs (Bachar et al., 2021). The emergence of the severe acute respiratory syndrome-coronavirus (SARS-CoV)-2 pandemic has highlighted our ability to swiftly and resolutely respond to a potential outbreak (Tournier and Kononchik, 2021). As a result, the search for new antiviral agents is now focusing not only on synthetic combinations but also on plant-origin metabolites (Perera and Efferth, 2012).

Medicinal plants have been used for centuries for healing, although their use has not always been scientifically supported. Today, they form the basis of the system of traditional medicine. Traditional medicine includes health practices, approaches, knowledge and beliefs about herbal, animal and mineral drugs, spiritual treatments, and manual procedures applied individually or in combination to diagnose, treat or prevent disease or maintain health (World Health Assembly, 2003). This knowledge is consolidated and available to the public thanks to ethnobotanical research. In recent years, scientists, along with new technologies and research methods, have been discovering new bioactive components and therapeutic possibilities of plants,

contributing to the development of innovative solutions in the treatment and prevention of diseases. This constant progress in plant research enables the wider use of herbal products in modern medicine (Beressa et al., 2021, Najmi et al., 2022).

This study aimed to summarize data from the literature on the antiviral effects of plants that were/are traditionally used in Bosnia and Herzegovina, as well as investigate the relationship between the traditional use of these plants and their potential antiviral properties.

2. Material and Methods

In this retrospective analysis, previously published ethnobotanical studies were used to gain insight into the use of plants in traditional medicine in Bosnia and Herzegovina (Zovko, 1890; Glück, 1892; Fazlagić, 1894, 1895; Kulinović, 1898; Bratić, 1903, 1908; Medić, 1904 a, b; Dragićević, 1909; Filipović-Fabijanić, 1964; Filipović-Fabijanić, 1968; Filipović-Fabijanić, 1969/1970, 1971; Redžić, 2007, 2010; Šarić-Kundalić et al., 2010 a,b, 2011, 2015, 2016; Fereier et al., 2015; Ginko et al., 2023); as well as the study Muratović and Parić (2023) combined these studies to provide an overview of plant species used throughout history until today. Relevant databases, like Web of Science, Scopus, and ScienceDirect (Elsevier), were used to search for medicinal plants with antiviral activity using keywords such as "antiviral activity" and "bioactive compounds."

3. Results

Out of the total number of 145 ethnobotanically researched and documented plant species (Muratović and Parić, 2023), this paper focuses on 56 taxa scientifically proven to have antiviral potential in addition to ethnobotanical use (Table 1.). This selection provides a better understanding of plants that, based on traditional knowledge, were used to treat various diseases and showed significant potential in combating viral infections.

Based on the data in (Table 1.), research has been conducted on the antiviral properties of various plant families, and some of them were dominant. The most prominent family was Lamiaceae, with ten species investigated for their antiviral potential. The Asteraceae family takes second place with eight plant species, while Rosaceae ranks third with six species. The Fabaceae family follows them with three, and the rest of the families have two or one plant species each.

Table 1. Medicinal plants in traditional use in Bosnia and Herzegovina (Muratović and Parić, 2023) and their antiviral potential

Scientific Name	**Family**	**Vernacular name**	**Part(s) of utilization**	**Therapeutic uses**	**Mode of utilization**	**Antiviral potential**	**References**
Agrimonia eupatoria L.	Rosaceae	petrovac, turica, turika	aerial part	anti-haemorrhagic, anti-inflammatory, diarrhea, hepatics, rheumatism	infusion	HBV*	Kwon et al., 2005
Alchemilla vulgaris	Rosaceae	vrkuta, gospin plašt, plahtica	aerial part	anti-hemorrhagic, anti-inflammatory, antiseptic, dysmenorrhea, hormonal disorders	infusion	SARS-CoV-2	Suručić et al., 2022
Angelica archangelica L.	Apiaceae	anđelika	aerial part	analeptic, asthma, flatulence, migraine	infusion	HSV-1 CVB3	Rajtar et al., 2017
Anthyllis vulneraria L.	Fabaceae	ranjenik	aerial part	contusion, cough, skin disorders, wound	infusion	HSV-1 EVC	Suganda et al., 1983
Arctium lappa L.	Compositae	čičak, repuh	root, leaf, fruit	antipruritic, aperitif, arteriosclerosis, diabetes, diuretic, eczema, hepatic, hyperglycemia, psoriasis	infusion	HSV IAV	Dias et al., 2017
Artemisia vulgaris L.	Compositae	divlji pelin, komonjika, komunika, crnobilj, crni pelin, umit	young shoots	antianemic, antipyretic, antispasmodic, aperitif, diabetes, diarrhea, diuretic, gastritis, hepatic, laxative, rheumatism	infusion, tincture	HSV	Xiao, 2023

Scientific Name	Family	Vernacular name	Part(s) of utilization	Therapeutic uses	Mode of utilization	Antiviral potential	References
Berberis vulgaris L.	Berberidacae	žutika, babnja, breberika	root, flower, bark	antiemetic, arteriosclerosis, diuretic, hypertension, rheumatism	infusion	EV	Wang et al., 2017
Betula pendula Roth	Betulaceae	breza	leaf, bark, fresh sap	antiinfective, diarrhea, dermatitis, diuretic, hepatic, hypertension.	nfusion, juice	HSV HIV	Vladimirov et al., 2019; Heidary Navid et al.,
Carlina acaulis L.	Compositae	kravljak, sikavac	root	urinary infection, hypertension, hepatitis, antiseptic for skin diseases.	nfusion, fresh juice, infusion	SARS-CoV-2	Wnorowska et al., 2022
Centaurea benedicta (L.) L.	Compositae	blaženi čkalj	leaf	cancer of stomach, strengthen of liver and spleen.	Infusion, tincture	SARS-CoV-2	Alhadrami et al., 2021
Ceratonia siliqua L.	Fabaceae	rogač, rožićak, kaluber	fruit	sore throat, dysmenorrhea, gastritis, diarrhea	infusion	HSV	Darwish et al., 2021
Chelidonium majus L.	Papaveraceae	rosopas, zarastovača, zmijino mlijeko	aerial part	dermatitis, rheumatism.	juice from the stem	HSV HIV HPV	Monavari et al., 2011; Musidlak et al.2022;Salehi
Cornus mas L.	Cornaceae	drijenak, drijen, drijenjina	fruit, sap from a tree	antipyretic, diabetes, diarrhea, respiratory disease, vitamin C deficiensis.	juice, infusion	HSV HIV	Lavoie et al., 2017; Okuda 2005
Crataegus monogyna Jacq.	Rosaceae	glog, bijeli glog	leaf, flower, fruit	arteriosclerosis, cardiotonic, hypertension.	infusion	HSV 1	Orhan et al., 2007

Scientific Name	Family	Vernacular name	Part(s) of utilization	Therapeutic uses	Mode of utilization	Antiviral potential	References
Equisetum arvense L.	Equisetaceae	livadska preslica, preslica,	aerial part	anti-anemic, antiinfective, diabetes, diuretic, rheumatism.	infusion	IAV	Moradi et al., 2017
Fagus sylvatica L.	Fagaceae	bukva	leaf	antiinflammatory	infusion	HSV	Pujol et al., 2016
Ficus carica L.	Moraceae	smokva	leaf	diabetes	infusion	HSV HPV	Ay and Duran, 2018; Ghanbari
Filipendula vulgaris Moench	Rosaceae	kraljica polja	aerial part	circulation, cough, fever, rheumatism	infusion, fresh juice	HIV	James et al., 2003
Foeniculum vulgare Mill.	Apiacaeae	komorač	aerial part	antianemic, anti-inflammatory, antipyretic, diarrhea, hypertension.	nfusion, syrup	HSV IAV SARS-CoV-2	Ibrahim and Moussa, 2021; Orhan et
Fragaria vesca L.	Rosaceae	šumska jagoda	leaf, rhizome, fruit	anti-anemic, antitussive, arteriosclerosis, dyspepsia, gastritis, hypertension, vitamin C deficiensis.	infusion	IAV CVB1 EVC	Nikolaeva-Glomb et al., 2013
Geranium macrorrhizum L.	Geraniaceae	zdravac planinski	rhizome	menstruation disorders, stomach disorder.	infusion, decoction	HSV IAV	Choi et al., 2019; Serkedjieva al al., 1998

Scientific Name	Family	Vernacular name	Part(s) of utilization	Therapeutic uses	Mode of utilization	Antiviral potential	References
Glycyrrhiza glabra L.	Fabaceae	sladić	root	hepatitis, hysteria, stomach disorders, sore throat, stone and sand in the kidney.	infusion, extract in oil olive	HSV HIV HBV SARS-CoV-2	Sato et al., 1996; Gotoh et al., 1987; Takahara et al., 1994;
Hedera helix L.	Araliaceae	bršljan	leaf	anti-emetic, anti-inflammatory, diuretic, hypertension, rheumatism.	infusion	IAV	Hong et al., 2015
Helichrysum italicum (Roth) G. Don	Compositae	smilje	flower	antianemic, antipyretic, migraine.	infusion	HIV	Chien et al., 2004
Hypericum perforatum L.	Clusiaceae	kantarion, bogorodičina trava, ivanova trava	aerial part	analeptic, antianemic, antiinfective, antifungal, asthma, diarrhea, dysmenorrhea, gastritis, hepatic, migraine, rheumatism.	infusion, oil	SARS-CoV-2 HIV	Mohamed et al., 2022; Zhang et al., 2017
Juglans regia L.	Juglandaceae	orah	leaf, immature fruits	dermatitis, diabetes, gastritis, hypo-hyperthyroidism, rheumatism.	infusion, syrup, honey	HIV EVC CVB1 HAdV	D'Angeli et al., 2021

Scientific Name	Family	Vernacular name	Part(s) of utilization	Therapeutic uses	Mode of utilization	Antiviral potential	References
Juniperus communis L.	Cupressaceae	kleka, smreka	galbulus, yang shots	antianemic, antiinfective, anti-inflammatory, diabetes, dyspepsia, gastritis, hepatics, laxative, rheumatism, scurvy.	infusion, juice, tincture	IAV	Najar et al., 2022
Laurus nobilis L.	Lauraceae	lovor	leaf, fruit	antitussive, flatulence, gastritis.	infusion	HSV1 SARS-CoV-2	Khodja et al., 2023
Lavandula angustifolia Mill. subsp. *angustifolia*	Lamiaceae	despik, lavanda	aerial part	analeptic, cardiotonic, gastritis, hypertension, migraine, rheumatism	infusion, oil	IAV	Abou et al., 2021
Marrubium vulgare L.	Lamiaceae	obična marulja, očajnica, smrduša	aerial part	antiseptic	infusion	HSV	Fayyad et al., 2014
Matricaria chamomilla L.	Compositae	kamilica	leaf, flower	antianemic, anti-inflammatory, antipyretic, arthritis, antispasmodic, dermatitis, diarrhea, diuretic, flatulence, gastritis, hypertension, migraine.	infusion	HSV EVC	Suganda et al., 1983

Scientific Name	Family	Vernacular name	Part(s) of utilization	Therapeutic uses	Mode of utilization	Antiviral potential	References
Melissa officinalis L.	Lamiaceae	melisa, matičnjak, pčelinja ljubica, limunčić	aerial part	analeptic, antiviral, asthma, cardiotonic, dyspepsia, gastritis, hypertension, laxative.	infusion	HSV HIV SARS-CoV-2	Behzadi et al., 2023
Mentha pulegium L.	Lamiaceae	verem trava	aerial part	analeptic, anti-inflammatory, gastritis.	infusion	HSV	Parsania et al., 2017
Nigella damascena L.	Ranunculaceae	čurokot, mačkov brk	seed	analeptic, hepatic.	infusion	SARS-CoV-2	Imran et al., 2022
Origanum vulgare L.	Lamiaceae	divlji origano, mravinac, vranilova	aerial part	analeptic, antipyretic, dyspepsia, gastritis, hepatic.	infusion	SARS-CoV-2	Zhang et al., 2014
Petasites hybridus (L.) G. Gaertn. & al.	Compositae	lopuh, veliki čičak, repuh	root, leaf	rheumatism	infusion	SARS-CoV-2	Urda et al., 2022
Plantago media	Plantaginaceae	trputac,srednja bokvica	leaf	antianemic, anti-hemorrhagic, anti-inflammatory, antipyretic, diarrhea, gastritis, hepatics, rheumatism.	infusion	HSV HAdV	Zhakipbekov et al., 2023; Musarra-Pizzo et al., 2021

Scientific Name	Family	Vernacular name	Part(s) of utilization	Therapeutic uses	Mode of utilization	Antiviral potential	References
Polygonatum odoratum	Asparagaceae	pokosnica	rhizome	blooding from trachea, cough, hemorrhoids, leucorrhea, liver disorders, uterus disorders, wound.	resh juice, infusion	IAV	Pang et al., 2020
Primula veris	Primulaceae	jaglac, jaglika	aerial part	analeptic, migraine, rheumatism.	infusion	IAV	Eliopoulos et al., 2022
Prunella laciniata	Lamiaceae	bijela celinčica	aerial part	asthma, diarrhea, liver, strengthen of heart	decoction, infusion	HIV	Oh et al., 2011
Punica granatum	Lythraceae	nar	bark, fruit	diarrhea	infusion	HSV2 IAV	Arunkumar et al., 2018; Moradi et
Rosmarinus officinalis	Lamiaceae	ruzmarin, zimrad	leaf	analeptic, cardiotonic, gastritis, hepatics, rheumatism	infusion	HSV	Al-Megrin et al., 2020
Rubus idaeus	Rosaceae	malina	leaf	antiinfective, gastritis	infusion	IAV CVB1 EVC	Nikolaeva-Glomb et al., 2013
Ruta graveolens	Rutaceae	ruta	aerial part	cardiotonic, laxative, rheumatism	infusion	HSV1	Ebrahimi et al., 2021
Salvia officinalis	Lamiaceae	kadulja, žalfija	aerial part	anti-inflammatory, antipyretic, diabetes	infusion	IAV	Abou Baker et al., 2021

Scientific Name	Family	Vernacular name	Part(s) of utilization	Therapeutic uses	Mode of utilization	Antiviral potential	References
Sambucus ebulus	Viburnaceae	aptovina, apt, burjan	leaf, root, fruit	antipruritic	juice	HSV1	Ghaffari et al., 2021
Sinapis arvensis	Brassicaceae	gorušica, hardala	seed	asthma	with honey	HSV1	Sharifi-Rad et al., 2017
Taraxacum F. H. Wigg. sect. *Taraxacum*	Compositae	maslačak, žućanik	root, leaf, flower	antianemic, antispasmodic, diabetes, eczema, hemorrhoids, hepatic, hepatitis, laxative, rheumatism	infusion, honey	HCV	Rehman et al., 2016
Teucrium chamaedrys	Lamiaceae	dupčac, stupčac, mravak, suhovrh	aerial part	antibacterial, diabetes, diarrhea, gastritis	infusion	HSV	Todorov et al., 2015
Urtica dioica	Urticaceae	žara, kopriva	whole plant	analgesic, antianemic, antipyretic, arteriosclerosis, dermatitis, diabetes, diuretic, dysmenorrhea, hepatics, rheumatism	infusion	HIV	Uncini et al., 2005

Scientific Name	Family	Vernacular name	Part(s) of utilization	Therapeutic uses	Mode of utilization	Antiviral potential	References
Vaccinium myrtillus	Ericaceae	borovnica, vrisinje	leaf, fruit	antianemic, anti-inflammatory, arteriosclerosis, diabetes, diarrhea, dyspepsia, gastritis, vitamin C and E deficiencies	infusion, juice	IAV CVB1 EVC SARS-CoV-2	Nikolaeva-Glomb et al., 2013
Vaccinium vitis-idaea	Ericaceae	brusnica	leaf, fruit	antiinfective, diuretic, rheumatism	infusion	IAV	Nikolaeva-Glomb et al., 2013
Veronica officinalis	Plantaginaceae	čestoslavica, dobričica	leaf, flower	antipruritic, gastritis, rheumatism	infusion	IAV	Mazurkova et al., 2020
Viola odorata	Violaceae	ljubica mirisna	leaf, flower	antitussive	infusion	SARS-CoV-2	Adel Mehraban et al., 2023
Viscum album	Loranthaceae	imela bijela	aerial part	analeptic, cardiotonic, dysmenorrhea, hypertension	nfusion, tincture	HPIV	Karagöz et al., 2003
Vitex agnus-castus	Lamiaceae	fratarski biber, konopljika	aerial part, seed	against high potency, for nervous balance, hysteria, menstrual disorders	infusion, ecoctin, powder	HSV HIV	Islam et al., 2024

*Acronym of virus: HBV (*Hepatitis B virus*), HCV (*Hepatitis C virus*), SARS-CoV-2 (*Severe Acute Respiratory Syndrome Coronavirus 2*), HSV-1 and 2 (*Herpes simplex virus* 1 and 2), EV (*Enterovirus*). CVB1 and B3 (*Coxsackie virus B1* and *B3*), EVC (poliovirus -Enterovirus C), IAV (*Influenza A* virus), HIV (*Human immunodeficiency virus*), HPV 1 (*Human papilloma virus*), HPV (*Human papilloma virus 2),* HAdV *(Human adenovirus),* HPIV *(Human parainfluenza virus*)

The most common form of utilization (Table 1.) is infusion, for which 53 plant species are used. Infusion is prepared by pouring hot water over plant parts, and it is one of the simplest and most widespread ways of preparing medicinal plants. Nine plant species are used for fresh juice. It is frequently prepared from fresh parts of the plant, such as leaves, stems or roots, and is used due to the high concentration of bioactive substances. The tincture, which involves alcohol to extract the plant components, is prepared from four plant species. Three plant species are used for decoction (the plant material boiled in water), two for syrup, honey and oil, and one for honey. These data clearly showed that infusion dominates, while the other forms have less frequent usage.

The distribution of bioactive compounds varies in different parts of plants. According to (Table 1.), it was obvious that in folk medicine, the aerial part of plants is predominantly utilized (confirmed for 22 plant species). Additionally, leaves of 21 species are used in preparations, fruits of 10, and flowers and roots of seven species. Less commonly used plant organs, such as tree bark and rhizomes, were found to be employed for three taxa and young shoots for two. Finally, unripe fruits, seeds, fresh juice, tree sap and the whole plant were confirmed for only one plant species.

Based on the available literature data on the antiviral potential of plants (Table 1.), we selected the most relevant viruses against which these plants showed activity. Among the findings, 28 plant species showed antiviral potential against the herpes simplex virus (HSV-1 and HSV-2), 17 showed an inhibitory effect on the influenza virus, 13 on SARS-CoV-2, and 11 against the human immunodeficiency virus (HIV), etc.

In the reviewing literature, the Lamiaceae family showed the most pronounced antiviral potential on 13 different viruses, followed by Compositae, Rosaceae, Fabaceae, etc. (Table 1.).

4. Discussion

Regarding the antiviral properties of plant families, Lamiaceae, Compositae, and Rosaceae are the most extensively studied. It was expected since they are rich in taxa and contain various bioactive compounds known for their antiviral properties. The leaves of these families' members are sources of flavonoids and phenolic acids, such as 4-Hydroxybenzoic acid, vanillic acid, and chlorogenic acid (Sytar et al., 2018).

The plants from these families have been used in folk medicine for centuries, and modern research has confirmed their effectiveness in combating viruses. Behzadi et al. (2023) reported that Melissa officinalis has an antiviral effect against HSV, HIV,

SARS-CoV-2, CPV, HBV, and HCV (Table 1.). Additionally, its effectiveness as an alternative therapy for several viral infections has been confirmed by Muratović and Parić (2023). M. officinalis is rich in organic active compounds, mainly essential oils (including citronellal, menthol, eugenol, linalool, and geraniol) and polyphenols (including rosmarinic acid, caffeic acid, chlorogenic acid, salicylic acid, ellagic acid, and quercetin). Its significant antiviral effect is due to the presence of rosmarinic acid in its methanol extract (Chen et al., 2017).

Another example is Vaccinium myrtillus, a species with significant antiviral potential against various viruses such as poliovirus type 1 (PV-1), coxsackievirus B1 (CV-B1), human respiratory syncytial virus A2 (HRSV-A2), influenza virus A/H3N2, SARS-CoV-2, and Coxsackie virus (Nikolaeva-Glomb et al., 2014). This species contains phenolic compounds, including chlorogenic acid, quercetin and arbutin, which have outstanding antioxidant capacity both in vitro and in vivo. These compounds are present in different representatives of the Ericaceae family (Colak et al., 2017; Ștefănescu et al., 2019). The Juglans regia has a wide range of applications in daily life (Muratović and Parić, 2023). This taxon has been proven to have antiviral activity against HIV, Poliovirus, Coxsackievirus B1, Adenovirus, Sindbis virus (SINV), and herpes simplex virus (HSV) due to its active components quercetin, myricetin, and naringenin (Bhat et al., 2023). Additionally, Glycyrrhiza glabra has been found to have significant antiviral effects against HSV, HIV, HBV, SARS2, and H5N1 viruses due to its active compounds glycyrrhizin and glycyrrhetinic acid, which belong to the group of triterpenoids (Wang et al., 2015).

Although more than 200 human viruses have been discovered, antiviral medications are available only for a limited number of infections that target proteins encoded by a single virus (such as influenza A and B, hepatitis B and C, herpes, and HIV), providing a narrow spectrum of coverage (Karim et al., 2023). The emergence or re-emergence of viruses with epidemic or pandemic potential, such as Ebola, SAR-CoV-1, and SAR-CoV-2, has repeatedly reminded us of the importance of developing broad-spectrum antiviral drugs (Geraghty et al., 2021). In this context, our results highlight the diversity and complexity of antiviral potential among different plant families.

Table 2 shows the relationship between ethnobotanical research in Bosnia and Herzegovina and the research about the antiviral potential of selected plants. Local communities noticed that certain plant species help in the treatment of specific symptoms. Microbiological studies have proven that the plants used in traditional medicine also have antiviral potential and that the symptoms caused by these viruses can be identified with the symptoms recognized by folk medicine for the same plant species.

One of the examples is the already mentioned blueberry, which has proven antiviral potential against the SARS-CoV-2 virus, whose most common symptoms are hemorrhage, high temperature, diarrhea, anemia, sore throat, cough and diabetes (Table 2.). At the same time, it is important to emphasize that in the traditional medicine of B&H, this plant is used for antianemic, anti-inflammatory, arteriosclerosis, diabetes, diarrhea, dyspepsia, gastritis, vitamin C and E deficiency (Table 1.).

However, it is important to emphasize that the symptoms of viral infection are often subjective and can vary from person to person. For example, hepatitis B virus and hepatitis C virus can cause chronic infections. Viral hepatitis can cause a wide spectrum of clinical presentations from a benign form with quite mild or no symptoms to acute liver failure and sometimes liver cancer or death (Cheung and Kwo, 2020).

Various host factors collectively shape an individual's response to pathogens such as age, genetic factors, immune system function, nutritional status, microbiome, underlying health conditions as well as environmental factors including living conditions, socioeconomic status and exposure to pollutants and various other aspects (Hayward, 2023). Therefore, these results highlight the complexity of the relationship between traditional knowledge and modern scientific findings in the context of the treatment of viral infections.

Table 2. Antiviral potential of the plants with ethnobotanical use in Bosnia and Herzegovina

Virus (symptoms)	Plant species (Muratović et Parić 2023)	Reference
Herpes simplex virus (skin disorders, eczema, dermatitis, sore throat, inflammation, elevated temperature, migraine, asthma, diarrhea, gastritis)	*Angelica archangelica*, *Anthyllis vulneraria*, *Arctium lappa*, *Artemisia vulgaris*, *Betula pendula*, *Ceratonia siliqua* L, *Chelidonium majus*, *Cornus mas*, *Fagus sylvatica*, *Ficus carica*, *Foeniculum vulgare*, *Glycyrrhiza glabra*, *Laurus nobilis*, *Melissa officinalis*, *Matricaria chamomilla*, *Mentha pulegium*, *Plantago media*, *Punica granatum*, *Sinapis arvensis*, *Teucrium chamaedrys*	Xiao et al., 2024; Banerjee et al., 2007; McMillan et al., 1993; Napier et al., 2018; Zhang et al., 2022; Colemont et al., 1990

Influenza virus (high fever, anemia, diarrhea, cough)	*Arctium lappa*, *Foeniculum vulgare*, *Fragaria vesca*, *Hedera helix*, *Juniperus communis*, *Polygonatum odoratum* (Mill.), *Punica granatum*, *Rubus idaeus*, *Salvia officinalis*, *Vaccinium myrtillus*, *Vaccinium vitis-idaea*, *Veronica officinalis*	InformedHealth, 2006; Rice et al., 1998; Boktor et al., 2024
Severe acute respiratory syndrome coronavirus 2 (hemorrhages, high fever, diarrhea, anemia, sore throat, cough, diabetes)	*Alchemilla vulgaris*, *Foeniculum vulgare*, *Glycyrrhiza glabra*, *Hypericum perforatum*, *Laurus nobilis*, *Vaccinium myrtillus*, *Viola odorata*	Steenblock et al., 2023; Cornea et al., 2022; Bergamaschi et al., 2021; Juthi 2023; Waliszewska-Prosół et al., 2021; Rai et al., 2023
Human immunodeficiency virus (hypertension, diarrhea, dermatitis, fever and elevated temperature)	*Betula pendula*, *Chelidonium majus*, *Cornus mas*, *Filipendula vulgaris*, *Helichrysum italicum*, *Hypericum perforatum*, *Juglans regia*, *Prunella laciniata*, *Urtica dioica*	Nguyen et al., 2022; Garg and Snke, 2017; Harimenshi et al., 2022;
Poliovirus (flu-like symptoms, cough)	*Fragaria vesca*, *Matricaria chamomilla*, *Vaccinium myrtillus*	Wolbert et al., 2024
Coxsackie virus (dermatitis, diarrhea)	*Juglans regia, Vaccinium myrtillus*	Valestra et al., 2016; Trayer and Gore, 2020
Hepatitis B virus (hepatitis, stomach problems)	*Agrimonia eupatoria*, *Glycyrrhiza glabra*	Liu et al., 2022
Human papillomavirus (no data)	No data	No data
Adenovirus (gastrointestinal disturbances)	*Juglans regia*, *Plantago media*	Kumthip et al., 2019
Enterovirus (No data)	No data	No data
Hepatitis C virus (hepatitis)	*Taraxacum* sp.	Basit et al., 2023
Human parainfluenza virus (no data)	No data	No data

Among the plants that have been used throughout history in folk medicine and today are completely forgotten, there are the following: *Anagalis arvensis*, *Fritillaria meleagris*, *Galanthus nivalis*, *Hioscyamys niger*, *Rubia tinctorum* (Muratović and Parić, 2023). The antiviral effect of these plants was proven in different studies. Thus, the *Anagalis arvensis* has an antiviral potential against Herpes simplex and Poliovirus (Amoros et al., 1987), *Fritillaria meleagris* against the Influenza virus (Kim et al., 2020), *Galanthus nivalis* against Hepatitis C virus (Ashfaq et al., 2011), *Hioscyamys niger* against Respiratory Syndrome Coronavirus 2 (Kosari et al., 2021, 2024) and *Rubia tinctorum* against rotavirus (Sun et al., 2016).

5. Conclusions

In recent years, there has been a growing interest and need for antiviral drugs due to the latest pandemic. Consequently, medicinal plants are receiving increased attention. Research has demonstrated that the long-standing use of medicinal plants in folk medicine can offer valuable insights for further studies into their active

components. This study highlights the importance of a multidisciplinary approach, which can provide a broader perspective and better solutions for this and other issues.

6. References

1. Abe, N., Ebina, T., & Ishida, N. (1982). Interferon induction by glycyrrhizin and glycyrrhetinic acid in mice. Microbiology and Immunology, 26, 535–539. doi: 10.1111/j.1348-0421.1982.tb00207.x.
2. Abou Baker, D.H., Amarowicz, R., Kandeil, A., Ali, M.A., & Ibrahim, E.A. (2021). Antiviral activity of Lavandula angustifolia L. and Salvia officinalis L. essential oils against avian influenza H5N1 virus. Journal of Agriculture and Food Research, 4:100135. doi: 10.1016/j.jafr.2021.100135.
3. Adel Mehraban, M.S., Shirzad, M., Mohammad Taghizadeh Kashani L., Ahmadian-Attari M.M., Safari A.A., Ansari N., Hatami H., & Kamalinejad M. (2023). Efficacy and safety of add-on Viola odorata L. in the treatment of COVID-19: A randomized double-blind controlled trial. Journal of Ethnopharmacology, 25;304:116058. doi: 10.1016/j.jep.2022.116058.
4. Aiken, C., & Chen, C.H. (2005). Betulinic acid derivatives as HIV- 1 antivirals, Trends in Molecular Medicine, 11(1)31-36. doi: 10.1016/j.molmed.2004.11.001.
5. Alhadrami, H.A., Sayed, A.M., Hassan, H.M., Youssif, K.A., Gaber, Y., Moatasim, Y., Kutkat, O., Mostafa, A., Ali, M.A., Rateb, M.E., Abdelmohsen, U.R., & Gamaleldin, N.M. (2021). Cnicin as an Anti-SARS-CoV-2: An Integrated In Silico and In Vitro Approach for the Rapid Identification of Potential COVID-19 Therapeutics. Antibiotics, 7;10(5):542. doi: 10.3390/antibiotics10050542.
6. Al-Megrin, W.A., AlSadhan, N.A., Metwally, D.M., Al-Talhi, R.A., El-Khadragy, M.F., & Abdel-Hafez, LJ.M. (2020). Potential antiviral agents of Rosmarinus officinalis extract against herpes viruses 1 and 2. Bioscience Reports, 26;40(6):BSR20200992. doi: 10.1042/BSR20200992.
7. Amoros, M., Fauconnier, B., & Girre, R.L. (1987). In vitro antiviral activity of a saponin from Anagallis arvensis, Primulaceae, against herpes simplex virus and poliovirus. Antiviral Research, 8(1):13-25. doi: 10.1016/0166-3542(87)90084-2.
8. Arunkumar, J., & Rajarajan, S. (2018). Study on antiviral activities, drug-likeness and molecular docking of bioactive compounds of Punica granatum L. to Herpes simplex virus - 2 (HSV-2). Microbial Pathogenesis, 118:301-309. doi: 10.1016/j.micpath.2018.03.052.
9. Ashfaq, U.A., Masoud, M.S., Khaliq, S., Nawaz, Z., & Riazuddin, S. (2011). Inhibition of hepatitis C virus 3a genotype entry through Glanthus Nivalis Agglutinin. Virology Journal, 20(8):248. doi: 10.1186/1743-422X-8-248.

10. Ay, E., & Duran, N. (2018). Investigation of the antiviral activity of Ficus carica L latex against HSV-2.33-37. doi: 10.24264/icams-2018.I.3.
11. Bachar, S.C., Mazumder, K., Bachar, R., Aktar, A., & Al Mahtab, M. (2021). A Review of Medicinal Plants with Antiviral Activity Available in Bangladesh and Mechanistic Insight Into Their Bioactive Metabolites on SARS-CoV-2, HIV and HBV. Frontiers in Pharmacology, 12,732891. doi: 10.3389/fphar.2021.732891.
12. Behzadi, A., Imani, S., Deravi, N., Mohammad Taheri, Z., Mohammadian, F., Moraveji, Z., Shavysi, S., Mostafaloo, M., Soleimani Hadidi, F., Nanbakhsh, S., Olangian-Tehrani, S., Marabi, M.H., Behshood, P., Poudineh, M., Kheirandish, A., Keylani, K., & Behfarnia, P. (2023). Antiviral Potential of Melissa officinalis L.: A Literature Review. Nutrition and Metabolic Insights, 12(16),11786388221146683. doi: 10.1177/11786388221146683.
13. Beressa, T.B., Deyno, S., Mtewa, A.G., Aidah, N., Tuyiringire, N., Lukubye, B., Weisheit, A., Tolo, C.U., & Ogwang, P.E. (2021). Potential Benefits of Antiviral African Medicinal Plants in the Management of Viral Infections: Systematic Review. Frontiers in Pharmacology, 24(12),682794. doi: 10.3389/fphar.2021.682794. PMID: 35002686; PMCID: PMC8740180.
14. Bhat, A.A., Shakeel, A., Rafiq, S., Farooq, I., Malik, A.Q., Alghuthami, M.E., Alharthi, S., Qanash, H., & Alharthy, S.A. (2023). Juglans regia Linn.: A Natural Repository of Vital Phytochemical and Pharmacological Compounds. Life (Basel), 13(2):380. doi: 10.3390/life13020380.
15. Bratić, T.A. (1903). Pabirci iz narodne medicine u Hercegovini. Glasnik Zemaljskog Muzeja. XV/I:153-180.
16. Bratić, T.A. (1908). Narodno liječenje. Iz vremena jedne ljekaruše iz 1843. godine. Glasnik Zemaljskog Muzeja. XX/III:343-362.
17. Chen, S.G., Leu, Y.L., Cheng, M.L., Ting, S.C., Liu, C.C., Wang, S.D., Yang, C.H., Hung, C.Y., Sakurai, H., Chen, K.H., & Ho, H.Y. (2017). Anti-enterovirus 71 activities of Melissa officinalis extract and its biologically active constituent rosmarinic acid. Scientific Reports, 7, 12264. doi: 10.1038/s41598-017-12388-2.
18. Cheung, A., & Kwo, P. (2020). Viral hepatitis other than A, B, and C: evaluation and management. Clinics in liver disease, 24(3), 405-419. doi: 10.1016/j.cld.2020.04.008.
19. Chien, N.Q., Hung, N.V., Santarsiero, B.D., Mesecar, A.D., Cuong, N.M., Soejarto, D.D., Pezzuto, J.M., Fong, H.H., & Tan, G.T. (2004). New O-acyl betulinic acids from Strychnos vanprukii Craib. Journal of natural products, 67, 994–998. doi: 10.1021/np030469i.
20. Choi, J. G., Kim, Y. S., Kim, J. H., & Chung, H. S. (2019). Antiviral activity of ethanol extract of Geranii Herba and its components against influenza viruses via

neuraminidase inhibition. Scientific reports, 9(1), 12132. doi: 10.1038/s41598-019-48430-8

21. Choudhary, P., Pant, K., & Kumar, V. (2024). Challenges in development of antiviral drugs and vaccines. In Pathogenic Viruses and Armamentarium Design (pp. 157-173). Academic Press.
22. Colak, N., Primetta, A.K., Riihinen, K.R., Jaakola, L., Grúz, J., Strnad, M., Torun,H., & Ayaz, F.A. (2017). Phenolic compounds and antioxidant capacity in different-colored and non-pigmented berries of bilberry (Vaccinium myrtillus L.). Food Bioscience, 20, 67-78. doi:10.1016/j.fbio.2017.06.004.
23. D'Angeli F., Malfa G.A., Garozzo A., Li Volti G., Genovese C., Stivala A., Nicolosi D., Attanasio F., Bellia F., Ronsisvalle S., & Acquaviva R. (2021) Antimicrobial, Antioxidant, and Cytotoxic Activities of Juglans regia L. Pellicle Extract. Antibiotics, 4;10(2),159. doi: 10.3390/antibiotics10020159
24. Darwish, W.S., Khadr, A.E.S., Kamel, M.A.E.N., Abd Eldaim, M.A., El Sayed, I.E.T., Abdel-Bary, H.M., Ullah, S., & Ghareeb, D.A. (2021). Phytochemical Characterization and Evaluation of Biological Activities of Egyptian Carob Pods (Ceratonia siliqua L.) Aqueous Extract: In Vitro Study. Plants. 10(12),2626. doi: 10.3390/plants10122626
25. Dias, M.M., Zuza, O., Riani, L.R., de Faria Pinto, P., Pinto, P.L.S., Silva, M.P., de Moraes, J., Ataíde, A.C.Z., de Oliveira Silva, F., Cecílio, A.B., & Da Silva Filho, A.A. (2017). In vitro schistosomicidal and antiviral activities of Arctium lappa L. (Asteraceae) against Schistosoma mansoni and Herpes simplex virus-1. Biomedicine & Pharmacotherapy, 94, 489-498. doi: 10.1016/j.biopha.2017.07.116.
26. Dragićević, T. (1909). Narodni lijekovi. Glasnik Zemaljskog Muzeja. XXI/III:461-478.
27. Ebrahimi, E., Mousavi-Jazayeri, S.M., Rezaee, M.B., & Parsania, M. (2021). Antiviral Effects of Aloe vera (L.) Burm.f. and Ruta Graveolens L. Extract on Acyclovir-Resistant Herpes Simplex Virus Type 1. Journal of Medicinal Plants and By-products, 1: 103-108. doi: 10.22092/jmpb.2021.352463.1286.
28. Eliopoulos, A.G., Angelis, A., Liakakou, A., & Skaltsounis, L.A. (2022). In Vitro Anti-Influenza Virus Activity of Non-Polar Primula veris subsp. veris Extract. Pharmaceuticals, 15(12), 1513. doi: 10.3390/ph15121513.
29. Fayyad, A.G.S., Ibrahim, N., & Yaakob, W.A. (2014). Phytochemical screening and antiviral activity of Marrubium vulgare. Malaysian Journal of Microbiology, 10(2), 106-111. doi: 10.21161/mjm.58013.
30. Fazlagić, H. (1894). Narodni lijekovi iz bilinstava u Bosni. Glasnik Zemaljskog Muzeja. VI/IV:800-802.

31. Fazlagić, H. (1895). Bajanje. Prilog narodnog lijekarstva Bosne i Hercegovine. Glasnik Zemaljskog Muzeja .VII/I:155-157.
32. Ferrier, J., Saciragic, L., Trakić, S., Chen, ECH., Gendron, R., Cuerrier, A., Balick, M., Redžić, S., Alikadić, E., & Arnason, J. (2015). An ethnobotany of the Lukomir highlanders of Bosnia & Herzegovina. Journal of Ethnobiology and Ethnomedicine, 11:81. doi: 10.1186/s13002-015-0068-5.
33. Filipović-Fabijanić, R. (1968). Narodna medicina istočne Hercegovine. Glasnik Zemaljskog Muzeja N. S. XXIII/Etnologija: 35-76.
34. Filipović-Fabijanić, R. (1964). Narodna medicina i narodna verovanja (u Žepi). Glasnik Zemaljskog Muzeja N.S. XIX/Etnologija:209-236.
35. Filipović-Fabijanić ,R. 1969/1970. O narodnoj medicini stanovništva Lištice s okolinom. Glasnik Zemaljskog Muzeja N.S. XXIV/XXV/Etnologija:319-335.
36. Filipović-Fabijanić, R. (1971). "Domaći ljekar" iz 1868. godine sa Širokog Brijega. Glasnik Zemaljskog Muzeja N.S. XXVI/Etnologija:117-178.
37. Ghaffari, H., Ataei-Pirkooh, A., Mirghazanfari, S.M., & Barati, M. (2021). Inhibition of herpes simplex virus type 1 infection by Sambucus ebulus extract in vitro. Medical Journal of The Islamic Republic of Iran, 35:9, doi: 10.47176/mjiri.35.9.
38. Ghanbari, A., Le Gresley, A., Naughton, D., Kuhnert, N., Sirbu, D., & Ashrafi, G.H. (2019). Biological activities of Ficus carica latex for potential therapeutics in Human Papillomavirus (HPV) related cervical cancers. Scientific Reports, 9(1):1013. doi: 10.1038/s41598-018-37665-6.
39. Geraghty, R.J., Aliota, M.T., & Bonnac, L.F. (2021). Broad-Spectrum Antiviral Strategies and Nucleoside Analogues. Viruses, 13, 667.
40. Ginko, E., Alajmovic Demirović, E., & Šarić-Kundalić, B. (2023). Ethnobotanical study of traditionally used plants in the municipality of Zavidovići, BiH. Journal of Ethnopharmacology. 302(Pt A):115888. doi: 10.1016/j.jep.2022.115888.
41. Glück, L. (1892). Narodni lijekovi iz bilinstva u Bosni. Etnografska študija. Glasnik Zemaljskog Muzeja IV/II:134-167.
42. Gotoh, Y., Tada, K., Yamada, K., Minamitani, M., Negishi, M., Fujimaki, M., Ikematsu, S., Hada, M., Mori, K., Ito, M. & Shigeta, S. (1987). Administration of glycyrrhizin to patients with human immunodeficiency virus infection. Igaku no Ayumi, 140, 619-620.
43. Hayward, M. (2023). The Influence of Host Factors on Susceptibility and Resistance to Infectious Diseases. Journal of Microbiology and Pathology, 7 (1), 169.
44. Heidary Navid, M., Laszczyk-Lauer, M.N., Reichling, J., & Schnitzler, P. (2024). Pentacyclic triterpenes in birch bark extract inhibit early step of herpes simplex

virus type 1 replication. Phytomedicine, 21;1273-1280. doi: 10.1016/j.phymed.2014.06.007.

45. Hoever, G., Baltina, L., Michaelis, M. Kondratenko, R, Baltina, L, Tolstikov, GA, Doerr, HW, & Cinatl, J. Jr. (2005). Antiviral activity of glycyrrhizic acid derivatives against SARS-coronavirus. J. Med Chem 48: 1256–1259. doi: 10.1021/jm0493008.
46. Hong, E.H., Song, J.H., Shim, A., Lee, B.R., Kwon, B.E., Song, H.H., Kim, Y.J, Chang, S.Y., Jeong, H.G., Kim, J.G., Seo, S.U., Kim, H., Kwon, Y., & Ko, H.J. (2015). Coadministration of Hedera helix L. Extract Enabled Mice to Overcome Insufficient Protection against Influenza A/PR/8 Virus Infection under Suboptimal Treatment with Oseltamivir. PLoS One, 10(6), e0131089. doi: 10.1371/journal.pone.0131089.
47. Ibrahim, N., & Moussa, A.Y. (2021). A comparative volatilomic characterization of Florence fennel from different locations: Antiviral Prospect. Food & Function. 12, 1498-1515. doi: 10.1039/D0FO02897E.
48. Imran, M., Khan, S.A., Abida Alshammari, M.K, Alkhaldi, S.M., Alshammari, F.N., Kamal, M., Alam, O., Asdaq, S.M.B., Alzahrani, A.K., & Jomah, S. (2022). Nigella sativa L. and COVID-19: A Glance at The Anti-COVID-19 Chemical Constituents, Clinical Trials, Inventions, and Patent Literature. Molecules, 27(9),2750. doi: org/10.3390/molecules27092750.
49. Islam, Z., Caldeira, G.I., Caniça, M., Islam, N., Silva, O. (2024). Vitex Genus as a Source of Antimicrobial Agents. Plants, 13(3):401. doi: 10.3390/plants13030401.
50. James, A.D., Mary, Jo B-G., Judi du, C. & Peggy-Ann, K.D. (2003). CRC Handboook of medicinal spices. Boca Raton, London, New York, Washington: CRC Press.
51. Karagöz, A., Onay, E., Arda, N., & Kuru, A. (2003) Antiviral potency of mistletoe (Viscum album ssp. album) extracts against human parainfluenza virus type 2 in Vero cells. Phytotherapy Research, 17(5),560-562. doi: 10.1002/ptr.1163.
52. Karim, M., Lo, C. W., & Einav, S. (2023). Preparing for the next viral threat with broad-spectrum antivirals. The Journal of Clinical Investigation, 133 (11), e170236. doi: 10.1172/JCI170236.
53. Khodja, Y.K.,Bachir-bey, M., Belmouhoub, M., Ladjouzi ,R., Dahmoune, F., & Khettal, B. (2023). The botanical study, phytochemical composition, and biological activities of Laurus nobilis L. leaves: A review. International Journal of Secondary Metabolite, 10(2), 269-296. doi: 10.21448/ijsm.1171836.
54. Kim, M., Nguyen, D.V., Heo, Y., Park, K.H., Paik, H.D., & Kim, Y.B. (2020). Antiviral Activity of Fritillaria thunbergii Extract against Human Influenza Virus H1N1 (PR8) In Vitro, In Ovo and In Vivo. Journal of Microbiology and Biotechnology, 30(2), 172-177. doi: 10.4014/jmb.1908.08001.

55. Kosari, M., Noureddini, M., Khamechi, S.P., Najafi, A., Ghaderi, A., Sehat, M., & Banafshe, H.R. (2021). The effect of propolis plus Hyoscyamus niger L. methanolic extract on clinical symptoms in patients with acute respiratory syndrome suspected to COVID-19: A clinical trial. Phytotherapy Research, 35(7), 4000-4006. doi: 10.1002/ptr.7116.
56. Kosari, M., Khorvash, F., Sayyah, M.K., Ansari Chaharsoughi, M., Najafi, A., Momen-Heravi, M., Karimian, M., Akbari, H., Noureddini, M., Salami, M., Ghaderi, A., Amini Mahabadi, J., Khamechi, S.P., Yeganeh, S., & Banafshe, H.R. (2024). The influence of propolis plus Hyoscyamus niger L. against COVID-19: A phase II, multicenter, placebo-controlled, randomized trial. Phytotherapy Research, 38(1), 400-410. doi: 10.1002/ptr.8032.
57. Kulkarni, S.A., Nagarajan, S.K., Ramesh, V., Palaniyandi, V., Selvam, S.P, & Madhavan, T. (2020). Computational evaluation of major components from plant essential oils as potent inhibitors of SARS-CoV-2 spike protein. Journal of Molecular Structure, 1221, 128823. doi: 10.1016/j.molstruc.2020.128823.
58.
59. Kulinović, M.F. (1898). Nešto o narodnom praznovjerju i liječenju u Muhamedovaca u Bosni Hercegovini. Glasnik Zemaljskog Muzeja X/II-III: 503-530.
60. Kurokawa, M., Shimizu, T., Watanabe, W., & Shiraki, K. (2010). Development of New Antiviral Agents from Natural Products. Open Antimicrobial Agents Journal, 2, 49-57. doi: 10.2174/1876518101002020049.
61. Kwon, D.H., Kwon, H.Y., Kim, H.J., Chang, E.J., Kim, M.B., Yoon, S.K., Song, E.Y., Yoon, D.Y., Lee, Y.H., Choi, I.S., & Choi, Y.K. (2005). Inhibition of hepatitis B virus by an aqueous extract of Agrimonia eupatoria L. Phytotherapy Research, 19(4), 355-358. doi: 10.1002/ptr.1689.
62. Lavoie, S., Côté, I., Pichette, A., Gauthier, C., Ouellet, M., Nagau-Lavoie, F., Mshvildadze, V., & Legault, J. (2017). Chemical composition and anti-herpes simplex virus type 1 (HSV-1) activity of extracts from Cornus canadensis. BMC Complementary and Alternative Medicine, 17, 123. doi: 10.1186/s12906-017-1618-2.
63. Mazurkova, N., Protsenko, M., Lobanova,I., Filippova, E., & Vysochina G. (2020). Antiviral activity of Siberian wild and cultivated plants. BIO Web of Conferences 24, 00051. doi.org/10.1051/bioconf/20202400051.
64. Medić, M. (1904a). Tri Ljekaruše. Glasnik Zemaljskog Muzeja. XVI/I:1-32.
65. Medić, M. (1904b). Tri Ljekaruše. (Nastavak i svršetak iz sveske I. str.1-32). Glasnik Zemaljskog Muzeja. XVI/II:195-223.
66. Mohamed, F.F., Anhlan, D., Schöfbänker, M., Schreiber, A., Classen, N., Hensel, A., Hempel, G., Scholz, W., Kühn, J., Hrincius, E.R., & Ludwig, S. (2022).

Hypericum perforatum and Its Ingredients Hypericin and Pseudohypericin Demonstrate an Antiviral Activity against SARS-CoV-2. Pharmaceuticals, 15(5), 530. doi: 10.3390/ph15050530.

67. Monavari, S.H.R., Keyvani, H., & Bokharaei-Salim, F. (2012) Evaluation of in Vitro antiviral activity of Chelidonium majus L. against Herpes Simplex virus type-1. African Journal of Microbiology Research, 6(20), 4360-4364. doi:10.5897/AJMR11.1350.
68. Moradi, M.T., Karimi, A., Lorigooini, Z., Pourgheysari, B., Alidadi, S., & Hashemi, L. (2017). In vitro anti influenza virus activity, antioxidant potential and total phenolic content of twelve Iranian medicinal plants. Marmara Pharmaceutical Journal, 21(4), 843-851. doi: 10.12991/mpj.2017.10.
69. Muratović, E., & Parić, A. (2023). Plant ethnomedicine in Bosnia and Herzegovina, past and present. Ethnobotany Research and Applications, 26, 1–27. doi: 10.32859/era.26.61.1-27.
70. Musarra-Pizzo, M., Pennisi, R., Ben-Amor, I., Mandalari, G., & Sciortino, M.T. (2021). Antiviral Activity Exerted by Natural Products against Human Viruses. Viruses, 13(5), 828. doi: 10.3390/v13050828.
71. Musidlak, O., Warowicka, A., Broniarczyk, J., Adamczyk, D., Goździcka-Józefiak, A., & Nawrot, R. (2022). The Activity of Chelidonium majus L. Latex and Its Components on HPV Reveal Insights into the Antiviral Molecular Mechanism. International Journal of Molecular Sciences, 23(16), 9241. doi: 10.3390/ijms23169241.
72. Najar, B., Nardi, V., Stincarelli, M.A., Patrissi, S., Pistelli, L., & Giannecchini, S. (2022). Screening of the essential oil effects on human H1N1 influenza virus infection: an in vitro study in MDCK cells. Natural Products Research, 36(12), 3149-3152. doi: 10.1080/14786419.2021.1944137.
73. Najmi, A., Javed, S.A., Al Bratty, M., & Alhazmi, H.A. (2022). Modern approaches in the discovery and development of plant-based natural products and their analogues as potential therapeutic agents. Molecules, 27(2), 349. doi: 10.3390/molecules27020349.
74. Nikolaeva-Glomb, L., Mukova, L., Nikolova, N., Badjakov, I., Dincheva, I., Kondakova, V., Doumanova, L., & Galabov, A. (2014). In Vitro Antiviral Activity of a Series of Wild Berry Fruit Extracts against Representatives of Picorna-, Orthomyxo- and Paramyxoviridae. Natural Product Communications, 9, 51-54. 10.1177/1934578X1400900116.
75. Oh, C., Price, J., Brindley, M.A., Widrlechner, M.P., Qu, L., McCoy, J.A., Murphy, P., Hauck, C., & Maury, W. (2011). Inhibition of HIV-1 infection by aqueous extracts of Prunella vulgaris L. Virology Journal, 8, 188. doi: 10.1186/1743-422X-8-188.

76. Okuda, T. (2005). Systematics and health effects of chemically distinct tannins in medicinal plants. Phytochemistry, 66, 2012–2031. doi: 10.1016/j.phytochem.2005.04.023.
77. Orhan, I., Ozçelik, B., Kartal, M., Özdeveci, B., D^ uman, H. (2007). HPLC Quantification of Vitexine-2”-O-rhamnoside and Hyperoside in Three Crataegus Species and Their Antimicrobial and Antiviral Activities. Chromatographia, 66, 153-157. doi: 10.1365/s10337-007-0283-x.
78. Orhan, İ.E., Özçelİk, B., Kartal, M., & Kan, Y. (2012). Antimicrobial and antiviral effects of essential oils from selected Umbelliferae and Labiatae plants and individual essential oil components. Turkish Journal of Biology, 36, 239-246. doi: 10.3906/biy-0912-30.
79.
80. Pang, X., Zhao, J.Y., Wang, Y.J., Zheng, W., Zhang, J., Chen, X.J., Cen, S., Yu, L.Y., & Ma, B.P. (2020). Steroidal glycosides, homoisoflavanones and cinnamic acid derivatives from Polygonatum odoratum and their inhibitory effects against influenza A virus. Fitoterapia, 146, 104689. doi: 10.1016/j.fitote.2020.104689.
81. Parsania, M., Rezaee, M.B., Monavari, S.H., Jaimand, K., Mousavi-Jazayeri, S.M., Razazian, M., & Nadjarha, M.H. (2017). Antiviral screening of four plant extracts against acyclovir resistant herpes simplex virus type-1. Pakistan Journal of Pharmaceutical Sciences, 30(4(Suppl.)):1407-1411.
82. Perera, C., & Efferth, T. (2012). Antiviral Medicinal Herbs and Phytochemicals. Journal of Pharmacognosy, 3(1), 45-48. doi: 10.9735/0976-884X.3.1.45-48.
83. Pompei, R., Flore, O., Marccialis, M.A., Pani, A., & Loddo, B. (1979). Glycyrrhizic acid inhibits virus growth and inactivates virus particles. Nature, 281, 689–690. doi: 10.1038/281689a0.
84. Pujol, C.A., Damonte, E.B., Turjan, J., Yanbo, K.Z., & Capek, P. (2016). The antiviral potency of Fagus sylvatica 4OMe-glucuronoxylan sulfates. Int J Biol Macromol, 87, 195-200. doi: 10.1016/j.ijbiomac.2016.02.048.
85. Rajtar, B., Skalicka-Woźniak, K., Świątek, Ł., Stec, A., Boguszewska, A., & Polz-Dacewicz, M. (2017). Antiviral effect of compounds derived from Angelica archangelica L. on Herpes simplex virus-1 and Coxsackievirus B3 infections. Food and Chemical Toxicology, 109(Pt 2):1026-1031. doi: 10.1016/j.fct.2017.05.011.
86. Redžić, S. (2007). The ecological aspect of ethnobotany and ethnopharmacology of population in Bosnia and Herzegovina. Collegium Antropologicum, 31(3), 869-890.
87. Redžić, S. (2010). Wild medicinal plants and their usage in traditional human therapy (Southern Bosnia and Herzegovina, W. Balkan). Journal of Medicinal Plants Research, 4(11), 1003-1027. doi: 10.5897/JMPR09.254.

88. Rehman, S., Ijaz, B., Fatima, N., Muhammad, S.A., & Riazuddin, S. (2016). Therapeutic potential of Taraxacum officinale against HCV NS5B polymerase: In-vitro and In silico study. Biomedicine & Pharmacotherapy, 83, 881-891. doi: 10.1016/j.biopha.2016.08.002.
89. Salehi, B., Kumar, N.V.A., Şener, B., Sharifi-Rad, M., Kılıç, M., Mahady ,G.B., Vlaisavljevic, S., Iriti, M., Kobarfard, F., Setzer, W.N., Ayatollahi, S.A., Ata, A., & Sharifi-Rad, J. (2018). Medicinal Plants Used in the Treatment of Human Immunodeficiency Virus. International Journal of Molecular Sciences, 19(5):1459. doi: 10.3390/ijms19051459.
90. Sato, H., Goto, W., Yamamura, J., Kurokawa, M., Kageyama, S., Takahara, T., Watanabe, A., & Shiraki, K. (1996). Therapeutic basis of glycyrrhizin on chronic hepatitis B. Antiviral Research, 30, 171– 177. doi: 10.1016/0166-3542(96)00942-4.
91. Sekizawa, T., Yanagi, K., & Itoyama, Y. (2001). Glycyrrhizin increases survival of mice with herpes simplex encephalitis. Acta Virologica, 45, 51–54.
92. Serkedjieva, J., & Ivancheva, S. (1998). Antiherpes virus activity of extracts from the medicinal plant Geranium sanguineum L. Journal of Ethnopharmacology, 64, 59–68. doi: 10.1016/s0378-8741(98)00095-6.
93. Sharifi-Rad, J., Salehi, B., Schnitzler, P., Ayatollahi, S.A., Kobarfard, F., Fathi, M., Eisazadeh, M., & Sharifi-Rad, M. (2017). Susceptibility of herpes simplex virus type 1 to monoterpenes thymol, carvacrol, p-cymene and essential oils of Sinapis arvensis L., Lallemantia royleana Benth. and Pulicaria vulgaris Gaertn. Cellular and Molecular Biology, (Noisy-le-grand), 63(8), 42-47. doi: 10.14715/cmb/2017.63.8.10.
94. Ștefănescu, B.E., Szabo, K., Mocan, A., & Crişan, G. (2019). Phenolic Compounds from Five Ericaceae Species Leaves and Their Related Bioavailability and Health Benefits. Molecules, 24(11), 2046. doi: 10.3390/molecules24112046.
95. Suganda, A.G., Amoros, M., Girre, L., & Fauconnier, B. (1983). Inhibitory effects of some crude and semi-purified extracts of indigenous French plants on the multiplication of human herpesvirus 1 and poliovirus 2 in cell culture. Journal of Natural Products, 46(5), 626-32. doi: 10.1021/np50029a006.
96. Sun, Y., Gong, X., Tan, J.Y., Kang, L., Li, D., Vikash Yang, J., & Du, G. (2016). In vitro Antiviral Activity of Rubia cordifolia Aerial Part Extract against Rotavirus. Frontiers in Pharmacology, 7, 308. doi: 10.3389/fphar.2016.00308.
97. Suručić, R., Radović Selgrad, J., Kundaković-Vasović, T., Lazović, B., Travar, M., Suručić, L., & Škrbić, R. (2022). In Silico and In Vitro Studies of Alchemilla viridiflora Rothm-Polyphenols' Potential for Inhibition of SARS-CoV-2 Internalization. Molecules, 27(16), 5174. doi: 10.3390/molecules27165174.

98. Sytar, O., Hemmerich, I., Zivcak, M., Rauh, C., & Brestic, M. (2018). Comparative analysis of bioactive phenolic compounds composition from 26 medicinal plants. Saudi Journal of Biological Sciences, 25(4), 631-641. doi: 10.1016/j.sjbs.2016.01.036.
99. Šarić-Kundalić, B., Ahmedbegović, A., Cilović, E., Ademović, Z., Kerleta-Tuzović, V., & Izić, B. (2015). Ethnobotanical study of traditionally used plants in human therapy of Trestenica and Tulovići, North-East Bosnia and Herzegovina. Pharmacia, 18(2):221-234.
100. Šarić-Kundalić, B., Dobeš, C., Klatte-Asselmeyer, V., Saukel, J. (2010a). Ethnobotanical study on medicinal use of wild and cultivated plants in middle, south and west Bosnia and Herzegovina. Journal of Ethnopharmacology, 131, 33-55. doi: 10.1016/j.jep.2010.05.061.
101. Šarić-Kundalić, B., Dobeš, C., Klatte-Asselmeyer, V., Saukel, J. (2011). Ethnobotanical survey of traditionally used plants in human therapy of east, north and north-east Bosnia and Herzegovina. Journal of Ethnopharmacology, 133, 1051-1076. doi: 10.1016/j.jep.2010.11.033.
102. Šarić-Kundalić, B., Fritz, E., Dobeš, C., & Saukel, J. (2010b). Traditional medicine in the pristine village of Prokoško lake on Vranica mountain, Bosnia and Herzegovina. Scientia Pharmaceutica, 78, 275-290. doi: 10.3797/scipharm.1003-06.
103. Šarić-Kundalić, B, Mazić, M, Djerić, S, & Kerleta-Tuzović, V. (2016). Ethnobotanical study on medicinal use of wild and cultivated plants on Konjuh Mountain, North-East Bosnia and Herzegovina. Technics Technologies Education Management, 11(3), 208- 221.
104. Takahara, T., Watanabe, A., & Shiraki, K. (1994). Effects of glycyrrhizin on hepatitis B surface antigen: a biochemical and morphological study. Hepatology Research, 21, 601–609. doi:10.1016/S0168-8278(94)80108-8.
105. Todorov, D., Pavlova, D., Hinkov, A., Shishkova, K., Dragolova, D., KapchinaToteva, V., & Shishkov, S. (2015) Effect of extracts derived from Teucrium chamaedrys L. on Herpes simplex virus type 2. Dokladi na Bulgarskata Akademiâ na Naukite 68, 1519–1526.
106. Tournier, J. N., & Kononchik, J. (2021). Virus eradication and synthetic biology: changes with SARS-CoV-2?. Viruses, 13(4), 569. doi: 10.3390/v13040569.
107. Trilla, A., Trilla, G., & Daer, C. (2008). The 1918 “Spanish Flu” in Spain. Clinical Infectious Diseases, 47(5), 668–673. doi:10.1086/590567.
108. Urda, L., Kreuter, M.H., Drewe, J., Boonen, G., Butterweck, V., & Klimkait, T. (2022). The Petasites hybridus CO2 Extract (Ze 339) Blocks SARS-CoV-2 Replication In Vitro. Viruses, 14(1), 106. doi: 10.3390/v14010106.

109. Uncini Manganelli, R.E., Zaccaro, L., & Tomei, P.E. (2005). Antiviral activity in vitro of Urtica dioica L., Parietaria diffusa M. et K. and Sambucus nigra L. Journal of Ethnopharmacology, 98(3), 323-7. doi: 10.1016/j.jep.2005.01.021.
110. Vladimirov, M.S., Nikolić, V.D., Stanojević, Lj.P., Nikolić, Lj.B., & Tačić, A. (2019). Common birch (Betula pendula Roth.): Chemical composition and biological activity of isolates. Advanced Technologies, 8. doi: 10.5937/SavTeh1901065V.
111. Xiao, A, Syed, HA, Tsuchiya, A. Eczema Herpeticum. (2024). In: StatPearls [Internet]. Treasure Island (FL). StatPearls Publishing; Available from: https://www.ncbi.nlm.nih.gov/books/NBK560781/
112. Wang, L., Yang, R., Yuan, B., Liu, Y., & Liu, C. (2015). The antiviral and antimicrobial activities of licorice, a widely-used Chinese herb. Acta Pharmaceutica Sinica B, 5(4):310-315. 10.1016/j.apsb.2015.05.005.
113. Wang, H., Li, K., Ma, L., Wu, S., Hu, J., Yan, H., Jiang, J., & Li, Y. (2017). Berberine inhibits enterovirus 71 replication by downregulating the MEK/ERK signaling pathway and autophagy. Virology Journal, 14(1):2. doi: 10.1186/s12985-016-0674-4.
114. Wnorowska, S., Targowska-Duda, K., Kurzepa, J., Wnorowski, A., & Strzemski, M. (2022). Carlina oxide inhibits the interaction of SARS-CoV-2 S glycoprotein with angiotensin-converting enzyme 2. Industrial Crops and Products, 187, 115338. doi: 10.1016/j.indcrop.2022.115338.
115. World Health Assembly (2003). “Traditional Medicine: Report by the Secretariat,”. Fifty-sixth world health assembly, Provisional agenda item 14.10 (Geneva, Switzerland: World Health Organization). Available at: https://apps.who.int/iris/handle/10665/78244.
116. World Health Organization (2024). WHO COVID-19 dashboard. https://data.who.int/dashboards/covid19/cases?n=o
117. Zhakipbekov, K., Turgumbayeva, A., Issayeva, R., Kipchakbayeva, A., Kadyrbayeva, G., Tleubayeva, M., Akhayeva, T., Tastambek, K., Sainova, G., Serikbayeva, E., Tolenova, K., Makhatova, B., Anarbayeva, R., Shimirova, Z., & Tileuberdi, Y. (2023). Antimicrobial and Other Biomedical Properties of Extracts from Plantago major, Plantaginaceae. Pharmaceuticals, 16(8), 1092. doi: 10.3390/ph16081092.
118. Zhang, X., Jiang, Y., Qian, H., Qu, X., & Han, K. (2022). The association between Herpes simplex virus type 2 and asthma: A cross-sectional study from National Health and Nutrition Examination Survey 1999-2016. Frontiers in Medicine, 9, 943706. doi: 10.3389/fmed.2022.943706
119. Zhao, J. H., Wang, Y. W., Yang, J., Tong, Z. J., Wu, J. Z., Wang, Y. B., & Shi, Z. H. (2023). Natural products as potential lead compounds to develop new antiviral

drugs over the past decade. European Journal of Medicinal Chemistry, 260:115726. doi: 10.1016/j.ejmech.2023.115726.

120. Zovko, I. (1890). Nekoliko narodnih lijekova. Glasnik Zemaljskog Muzeja, II/II:315-316.

121. Zumla, A., Hui, D. S., & Perlman, S. (2015). Middle East Respiratory Syndrome. Lancet, 386 (9997), 995–1007. doi:10.1016/S0140-6736(15)60454-8.