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The effect of competition between adult trees on natural regeneration of fir in beech-fir (with spruce) stands on Bjelašnica mountain

Utjecaj konkurencije odraslih stabala na podmlađivanje jele u šumama bukve i jele (sa smrčom) na Bjelašnici

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ABSTRACT

Silver fir is one of the most important tree species not only in Bosnia and Herzegovina, but also in whole of Europe. For natural regeneration of fir, the most important factors are site condition, share of fir in the stand and tree species composition. The aim of this study was to determine if there are statistically important differences in the number of seedlings and height increment at different competition situations between adult trees. Study area was located at Bjelašnica mountain. Data were collected on circular plots with a radius of 12.62m for trees with dbh above 5 cm, and radius 3 m for regeneration layer. The competition is expressed using Hegyi competition index, where for the calculation a dominant tree from each quadrant was used. We analysed the total number of fir individuals in regeneration layer and height increment for categories 50-130 cm height and 0.1-5 cm dbh. The results showed that there are no statistically significant differences in the number of for seedlings at different values of the Hegye index. Statistically significant differences were found in terms of height increment. Height increment decreased with increasing competition between trees.

Key words: *regeneration, silver fir, competition, Hegyi index, height increment*

INTRODUCTION - *Uvod*

Jela (*Abies alba* Mill.) je jedna od najznačajnijih vrsta drveća ne samo u Bosni i Hercegovini nego i u Evropi, iz mnogih ekoloških i ekonomskih razloga. Smatra se temeljnom vrstom u šumskim ekosistemima prebornog načina gospodarenja zbog njene tolerancije na zasjenu, plastičnost na uvjete okoline i heterogene vertikalne strukture sastojine (Mauri i dr. 2016). Tako su, naprimjer, u istraživanju Cavlovic i dr. (2008) u podstojnoj etaži 161 godinu staroj kulturi smrče evidentirali prisustvo jedinke jele, prečnika 5.2 cm, visine oko 2.91 m, a čija je starost iznosila 93 godine.

Brojni su faktori koji limitiraju prirodno podmlađivanje jele (Dobrowolska i dr. 2017; Grassi i dr. 2004; Klopčič i dr. 2015; Świerkosz i dr. 2014), kao što su, naprimjer, sastav vrsta drveća u sastojini (Dobrowolska 1998), divljač (Jarni i dr. 2004), neadekvatni uzgojni tretmani (Bernadzki 2008) i slično. Pojava i razvoj prirodnog podmlatka

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ovisi i od karakteristika površinskog sloja tla (Grunda 1972) i konkurencije prizemne vegetacije (Jaworski 1973). Rezultati istraživanja do koje je došla Dobrowolska (1998) te Dobrowolska i Bolibok (2019) ukazuju da tri osnovne karakteristike sastojine: uslovi staništa, udio jele u sastojini i sastav vrsta drveća, igraju veoma važnu ulogu na podmlađivanje jele, dok istraživanje Dubravac i dr. (2007) ukazuje i na značaj sklopa krošanja. Pored toga, značajan faktor su i mikroklimatski uvjeti u sastojini, a istraživanje Ugarković i dr. (2018) ukazuje da se to u prvom redu odnosi na temperaturu zraka, relativnu vlažnost zraka i temperaturu tla, dok Dubravac i dr. (2007) još navode i vlažnost tla. Za klijanje i preživljavanje potrebno je svega 1% od ukupne dnevne svjetlosti, dok za intenzivniji rast je potrebno višestruko više (Ammer 1996). Za 5–8 godina stare biljke jele optimalna količina svjetlosti je 10–18%, dok za starije jedinke i do 25% od ukupne dnevne svjetlosti (Robakowski i dr. 2004). Dosadašnji način gospodarenja na Igmanu doveo je do toga da je prekidanje sklopa uglavnom bilo prejako, usljed čega je došlo do intenzivnog priliva svjetla. Zato je na mnogim površinama došlo do zakorovljavanja, što je gotovo onemogućilo pojavu prirodnog podmlatka, a ukoliko se i javio, ugušio ga je veoma bujan korov. Zato bi se moglo reći da je najčešći uzrok izostanka prirodnog podmlatka upravo prejak priliv svjetla, sa svim negativnim posljedicama (Pintarić 1970).

Konkurentski odnosi između drveća uzrokovani su neravnomjernim prostornim rasporedom drveća, vrsta i mikroklimom (Wang i dr. 2020). Različite individue trpe različite pritiske u borbi za svjetlom, vlagom, hranjivim materijama i drugim resursima (Weiskittel i dr. 2011), što rezultira fiziološkim slabljenjem ili odumiranjem biljaka. Prema tome, od konkurentskog pritiska drugih vrsta ovisi i socijalni položaj neke vrste drveća u sastojini, a samim time i količina svjetla koju dobiva. Poznato je da od količine svjetla u velikoj mjeri ovisi i obilnost plodonošenja (Mekić 1998), kao jedan od glavnih preduvjeta za prirodno podmlađivanje. Količina svjetla predstavlja također i jedan od najvažnijih resursa za preživljavanje, pojavu i rast podmlatka (Claveau i dr. 2002; Pacala i dr. 1994). Podmladak koji raste uz prisustvo više svjetla je generalno veći i proizvodi više biomase od podmlatka sa manjim prilivom svjetla, bez obzira na vrstu drveća i njene karakteristike (Chen 1997; Lilles i Astrup 2012).

Cilj ovog rada je istražiti utjecaj konkurencije između odraslih stabala na podmlađivanje jele. Kroz istraživanje će se pokušati utvrditi postoje li značajne razlike u brojnosti podmlatka i visinskom prirastu pri različitim konkurentskim odnosima odraslih stabala.

MATERIAL AND METHODS - *Materijal i metode istraživanja*

STUDY AREA - *Područje istraživanja*

U širem smislu područje istraživanja locirano je u unutrašnjim Dinaridima, tačnije sjeverne i sjeveroistočne padine Bjelašnice. Po teritorijalno-prostornom uređenju obuhvata ŠPP "Igmansko", GJ "Igman" odnosno u užem smislu odjele 111, 113, 114 i 115. U fitocenološkom smislu radi se uglavnom o šumama bukve i jele sa smrčom (*Abieti-Fagetum iliricum* Fuk. et. Stef. 1958), dok su dijelom obuhvaćene i subalpinske bukove šume. U vertikalnom pogledu. područje istraživanja obuhvata dijapazon od 1200 m n. v. do 1600 m n. v. Srednja godišnja temperatura zraka, za period od 2003. do 2014. godine, (meteorološka stanica Bjelašnica), iznosila je 1,75 °C, što upućuje na izrazit planinsko-alpski karakter klime ovog područja. Srednja godišnja količina padavina za vrh Bjelašnice iznosi 1.396 mm. Najsušniji mjeseci (mjeseci sa najmanjom količinom padavina) su april, maj i august, dok su oktobar, novembar i decembar mjeseci u kojima dolazi najveća količina padavina. Od ukupne količine padavina u toku vegetacionog perioda, na Bjelašnici padne 23,66% od ukupne količine padavina. U geološkom smislu područje je uglavnom izgrađeno od krečnjaka i dolomita. Najzastupljenija zemljišta su smeđa krečnjačka zemljišta (kalkokambisoli), krečnjačke crnice (kalkomelanosoli), te u manjoj mjeri ilimerizirana zemljišta (luvisoli). Pobrojani tipovi zemljišta pojavljuju se pojedinačno ili u mozačnim kombinacijama kalkomelanosol-kalkokambisol na nagnutim predjelima, te kalkomelanosol-kalkokambisol-luvisol na zaravnjenijim terenima odnosno vrtačama. Na određenim lokalitetima se mogu još uvijek susresti i inicijalne forme zemljišta.

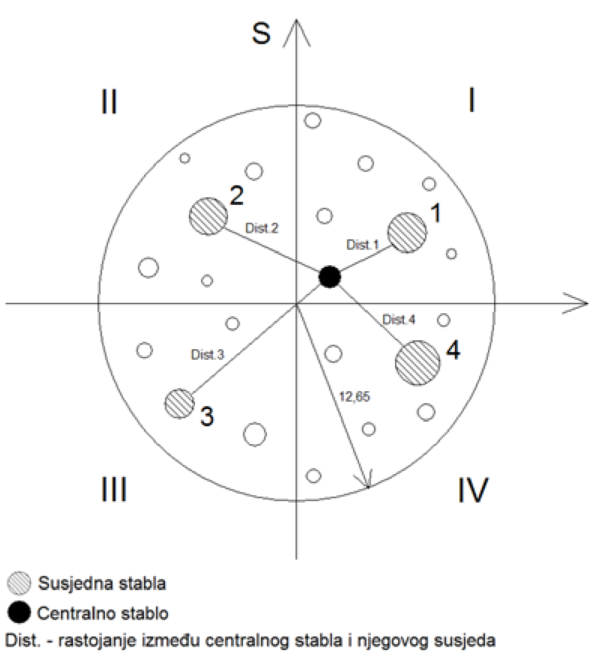
RESEARCH OBJECT AND DATA COLLECTION - *Objekt istraživanja i prikupljanje podataka*

Objekat istraživanja u ovom radu bile su eksperimentalne plohe kružnog oblika raspoređene sistematski u obliku mreže u razmacima od 100 metara. Mreža je položena u tri transekta po 27 ploha koji se prostiru kroz šumska odjeljenja broj: 111, 113, 114 i 115 gospodarske jedinice "Igman", lokalitet Ravna vala. Za utvrđivanje strukturnih karakteristika sastojine postavljene su kružne plohe fiksnog radijusa r = 12,62 m (površine 500 m^2) i prikupljeni su sljedeći podaci: pripadnost vrsti drveća, prečnik stabla na 1.3 m (stabla prečnika većeg od 5 cm), visina i položaj stabala u odnosu na centar kruga polarnom metodom (četiri dominantna stabla, u svakom kvadrantu po jedno po stranama svijeta). Podmladak je evidentiran s obzirom na brojnost i pripadnost datoj vrsti, a prema uzrastu je klasificiran na (Lojo i dr. 2008):

– ponik uzrasta 0,1–9,9 cm,
– podmladak uzrasta 10,0–49,9 cm,
– podmladak uzrasta 50,0–130,0 cm i
– podmladak prsnog prečnika 0,1–5,0 cm

Za dvije najviše uzrasne kategorije podmlatka (od 50 do 130 cm visine i prsnog prečnika od 0,1 do 5 cm) utvrđen je visinski prirast za zadnjih 10 godina. Visinski prirast je utvrđen mjerenjem dužine internodija po godinama, ukupno 10 godina od godine mjerenja. Mjerenje je vršeno pomoću lenjira ili u slučaju većih biljaka pomoću Vertexa IV.

Za procjenu konkurencije između stabla i procjenu utjecaja konkurencije na brojnost i kvalitet jelovog podmlatka, primijenjen je indeks po Hegyiu. Kao ulazni podaci korišteni su prsni prečnici i rastojanja između stabala. Kao centralno stablo uzeto je stablo koje je najbliže centru primjerne plohe, a kao konkurentska stabla se teoretski mogu uzeti sva stabla na primjernoj plohi, što daje tačnije vrijednosti samo za stabla u sredini plohe. U ovom radu u obračun su uzeta četiri dominantna stabla (stabla najvećih dimenzija po prečniku i visini), po jedno u svakom kvadrantu (prostor koji ograničavanju pravci prema glavnim stranama svijeta) i centralno stablo (stablo najbliže centru kruga) (slika 1).



Slika 1. Primjer odabira stabala za računanje Hegyi indeksa po kvadrantima po stranama svijeta

Figure 1. Example of tree sampling used for calculating Hegyi index per quadrant and direction

DATA PROCESSING - *Obrada podataka*

Svi prikupljeni podaci o sastojini i podmlatku uneseni su sa terenskih manuala u *MS Excel* u kojem su jednim dijelom obrađeni ili pripremljeni za importovanje u statističke programe *Statistica* i *STATGRAPHICS Centurion*.

Hegyiev indeks izračunat je po sljedećem obrazcu:

$$\text{Hegyi index} = \sum_{j=1}^{n} \frac{d_j}{d_i} \cdot DIST$$

gdje je:

n = broj susjednih stabala

d = prsni prečnik centralnog stabla "*i*" i njegovog susjeda "*j*"

DIST = rastojanje između centralnog stabla "*i*" i njegovog susjeda "*j*"

S obzirom na to da je u analizu uzeta 81 eksperimentalna ploha kružnog oblika i da je za svaku izračunat Hegyi indeks, u cilju jasnijeg sagledavanja zavisnosti ukupne brojnosti podmlatka jele i visinskog prirasta dvije najviše uzrasne kategorije podmlatka jele od Hegyi indeksa, dijapazon izračunatih indeksa je podijeljen u 6 intervala i to:

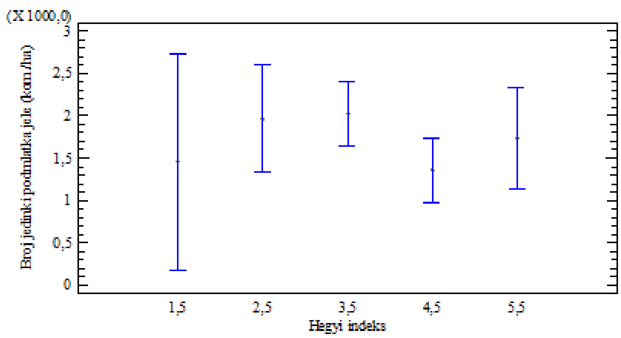
– 0,5 (0,00–0,99)
– 1,5 (1,00–1,99)
– 2,5 (2,00–2,99)
– 3,5 (3,00–3,99)
– 4,5 (4,00–4,99)
– 5,5 (5,00–6,00)

Vrijednosti Hegyievog indeksa kretale su se u dijapazonu od 0,00 do 9,63. Prilikom analize nisu razmatrane plohe sa vrijednostima indeksa iznad 6.

RESULTS - *Rezultati istraživanja*

EFFECT OF COMPETITION BETWEEN TREES ON ABUNDANCE OF FIR SEEDLINGS - *Utjecaj konkurencije između stabala na brojnost podmlatka jele*

Za ispitivanje utjecaja konkurencije stabala na brojnost podmlatka jele izvršena je analiza varijanse (ANOVA) i rezultati su prikazani na grafikonu 1. sa odgovarajućim LSD intervalima.



Grafikon 1. Zavisnost ukupnog broja podmlatka jele od vrijednosti Hegyi indeksa

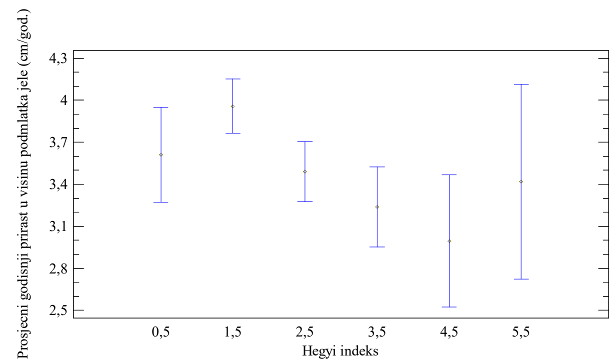
Graph 1. The dependence of silver fir seedlings occurrence for different values of Hegyi index.

Analizom varijanse je utvrđeno da ne postoji statistički značajna razlika između ukupne brojnosti podmlatka jele na plohama sa različitim Hegyi indeksom (P > 0,05), tj. konkurencija stabala ne igra značajnu ulogu na pojavu jelovog podmlatka. Na osnovu grafikona vidimo da je najveća pojedinačna brojnost podmlatka zabilježena na plohi sa manjom vrijednošću Hegyievog indeksa, odnosno manjom konkurencijom. Povećanjem konkurencije maksimalna brojnost podmlatka sa pojedinačnih ploha opada. Na tim plohama je ujedno i varijabilnost u pogledu brojnosti prirodnog podmlatka najveća i sa povećanjem konkurencije ta varijabilnost u pogledu pojave podmlatka se smanjuje. Najmanji varijabilitet se javlja pri središnjoj vrijednosti Hegyievog indeksa od 3.5. Na tim plohama je prosječno zabilježeno najviše podmlatka jele, a nešto manje na plohi sa vrijednosti indeksa od 2.5. Sa povećanjem ili smanjenjem konkurencije od refentne (3.5) prosječna brojnost podmlatka opada.

EFFECT OF COMPETITION BETWEEN TREES ON HEIGHT INCREMENT - *Utjecaj konkurencije stabala na godišnji visinski prirast podmlatka jele*

Utjecaj konkurencije na visinski prirast jele analiziran je za dvije uzrasne kategorije: (I) 50–130 cm, i (II) 0.1–5 cm. Za ispitivanje utjecaja izvršena je analiza varijanse i rezultati su prikazani na grafikonu 2.

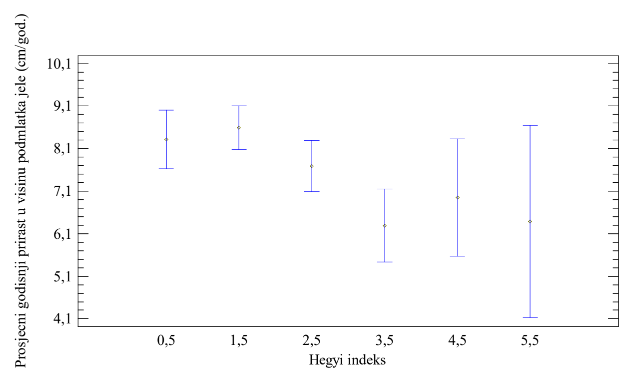
Analizom varijanse utvrđeno je da postoje statistički značajne razlike u visinskom prirastu jele za uzrasnu kategoriju od 50 do 130 cm pri različitim vrijednostima Hegyievog indeksa (P = 0.02). Na osnovu prethodnog grafikona, vidimo da je najveći visinski prirast zabilježen u vrijednosnom razredu Hegyi indeksa od 1.5. U spomenutom razredu visinski prirast ujedno je i prosječno najveći i najmanja je varijabilnost. Sa povećanjem konkurencije visinski prirast je sve manji. Najmanja srednja vrijednost je pri vrijednosti indeksa od 4.5. Najveća varijabilnost je u posljednjem vrijednosnom razredu od 5.5, gdje su zabilježene pojedinačne vrijednosti visinskog prirasta skoro jednake maksimalnim vrijednostima razreda od 1.5.



Grafikon 2. Zavisnost prosječnog godišnjeg prirasta u visinu podmlatka jele uzrasne kategorije od 50 do 130 cm visine od Hegyi indeksa.

Graph 2. The dependence of average yearly height increment of height class 50 to 130 cm for different Hegyi index values

Na narednom grafikonu predstavljena je zavisnost prosječnog godišnjeg prirasta u visinu podmlatka jele uzrasne kategorije od 0,1 do 5,0 cm prsnog prečnika od Hegyi indeksa.



Grafikon 3. Zavisnost prosječnog godišnjeg prirasta u visinu podmlatka jele uzrasne kategorije od 0,1 do 5,0 cm prsnog prečnika od Hegyi indeksa

Graph 3. The dependence of average yearly height increment of dbh class 0.1 to 5 cm for different Hegyi index values

Prema rezultatima analize varijanse (ANOVA), visinski prirast podmlatka jele, uzrasne kategorije od 0,1 do 5,0 cm prsnog prečnika, statistički značajno se razlikuju u zavisnosti od vrijednosti Hegyi indeksa (P = 0,025) pri vjerovatnoći od 95%. Najveće vrijednosti visinskog prirasta podmlatka jele zabilježene su pri manjim vrijednostima Hegyievog indeksa, odnosno pri manjoj konkurenciji. Prosječno najveći visinski prirast jele zabilježen je pri vrijednosti indeksa od 1.5, a zatim pri 0.5, dok sa povećanjem konkurencije visinski prirast podmlatka jele opada. Sa povećanjem konkurencije povećava se i varijabilnost u priraščivanju u visinu, pri čemu je najveća pri najvećoj vrijednosti Hegyi indeksa. Visinski prirast u tom vrijednosnom razredu kreće se od 4 cm do 8.7 cm godišnje.

DISCUSSION - *Diskusija*

U ovom radu analiziran je utjecaj konkurencije odraslih stabala izražen Hegyievim indeksom na ukupnu brojnost i visinski prirast za dvije uzrasne kategorije jelovog podmlatka.

Istraživanjem je utvrđeno da ne postoji statistički značajna veza između brojnosti prirodnog podmlatka jele i konkurencije između odraslih stabala. Do sličnih rezultata došli su i Paluch i dr. (2016). Oni su istraživanjem utvrdili da gustina sastojine u mješovitim sastojinama bukve, jele i smrče nema statistički značajan efekat na prirodno podmlađivanje jele, već da je podmlađivanje uslovljeno mikroklimatskim uvjetima. Prema istim autorima, povoljni mikroklimatski uvjeti karakterišu se većim udjelom smrče. Rezultati istraživanja Dobrowolska (1998) ukazuju da tri osnovne karakteristike sastojine: uslovi staništa, udio jele u sastojini i sastav vrsta drveća, igraju veoma važnu ulogu na podmlađivanje jele. Najlošiji uvjeti za podmlađivanje jele su u sastojinama sastavljenih od jasena, johe hrasta, trepetljike, lipe i sl., što je u vezi sa nepovoljnim režimom svjetla (Dobrowolska 2008, 1998). Brojna istraživanja su pokazala da je dostupnost svjetla jedan od ključnih faktora na razvoj i preživljavanje podmlatka (Hunziker i Brang 2005; Stancioiu i O'Hara 2006), dok na prostorni raspored podmlatka veću ulogu igraju edafski faktori, tačnije forma humusa (Paluch 2006). Na osnovu toga se najveća zabilježena brojnost podmlatka jele pri najmanjoj vrijednosti Hegyievog indeksa može objasniti povoljnijim uvjetima svjetla u odnosu na plohe pri većoj konkurenciji. Sa druge strane, velika varijabilnost u tom vrijednosnom razredu je u vezi sa drugim faktorima koji nisu uzeti u razmatranje u ovom radu, kao što je npr. udio jele i njen raspored na plohama, broj zrelih stabala jele i sl. Istraživanje Ivojević i dr. (2021) pokazalo je da je brojnost podmlatka jele veća što je udio jele veći u omjeru smjese. Najveća prosječna brojnost podmlatka zabilježena pri indeksu konkurencije od 3.5, može se objasniti činjenicom da je tu najmanja varijabilnost, što ukazuje na povoljniji omjer smjese jele, i da se radi uglavnom o zrelim stablima. Visoka brojnost podmlatka pri najvećoj vrijednosti Hegyievog indeksa u vezi je sa visokom tolerantnošću jele na zasjenu. Klopčič i dr. (2015) navode da jela podnosi zasjenu i pritisak sa strane i do nekoliko decenija, dok za klijanje i preživljavanje zahtijeva svega 1% od svjetlosti otvorenog prostora (Ammer 1996, Röhrig i dr. 2020).

Za obje uzrasne kategorije utvrđene su statistički značajne razlike između visinskog prirasta i Hegyi indeksa, odnosno od konkurencije između odraslih stabala koja se nalaze u neposrednom okruženju posmatranog podmlatka. Visinski prirast u pravilu opada sa povećanjem konkurencije odraslih stabala za obje uzrasne kategorije. Do sličnih opažanja došli su i drugi autori (Stancioiu i O'Hara 2006; Laiho i dr. 2014, Vickers i dr. 2014). Oni su utvrdili da je veza između konkurencije u nadstojnoj etaži, odnosno gustine i rasta juvenilnih stabala uglavnom negativno eksponencijalna, tj. visinski prirast opada sa porastom konkurencije. Pozitivna reakcija podmlatka na smanjenje konkurencije u nadstojnoj etaži najčešće se dovodi u vezu sa povećanjem priliva svjetla, ali isto tako može biti odraz i poboljašnje vodnog režima i režima hranjivih materija zbog brže mineralizacije organske materije i/ili smanjenja konkurencije korijenja sa odraslim stablima (Aussenac 2000; Bauhus i Bartsch 1995). Visoke pojedinačne vrijednosti visinskog prirasta kao i visoka varijabilnost pri največoj vrijednosti Hegyievog indeksa ukazuje na heterogene uvjete na tim plohama. Na takvim plohama ključni faktori za rast i razvoj podmlatka su neki faktori kao što su ranije spomenuti omjer smjese, raspored vrsta drveća na plohi, njihova brojnost, sklop krošanja a neizostavan je i pozitivan efekat konkurencije u podmlatku na visinski prirast uslijed borbe za prostor.

CONCLUSION - *Zaključak*

Na osnovu svega navedenog može se konstatovati da konkurencija između odraslih stabala nema značajan utjecaj na pojavu, odnosno brojnost podmlatka jele, ali ima značajan utjecaj na njegov prirast u visinu i uopće na njegov rast i razvoj u sastojini. U tu svrhu, prilikom provođenja uzgojnih zahvata, potrebno je voditi računa o prostornom rasporedu stabala i njihovoj gustoći kako bi se osigurao optimalan rast podmlatka. Brojnost prirodnog podmlatka jele zavisi od drugih faktora, u prvom redu mikroklimatskih uvjeta naročito uslova svjetla, a zatim i od omjera smjese (udjela jele), kao i prisustva drugih vrsta drveća, sklopa krošanja itd. Zbog toga bi prilikom provođenja zahvata bilo nužno težiti ka stvaranju povoljnijih uvjeta za podmlađivanje jele, što podrazumijeva u prvom redu optimalan priliv svjetla i mikroklimatske uvjete. Odnos između visinskog prirasta i konkurencije stabala se može opisati negativnom eksponencijalnom krivom, što znači da visinski prirast opada sa povećanjem konkurencije. To ukazuje na važnost pravilnog izbora stabala za sječu, odnosno važnost provođenja uzgojnih zahvata, kako bi se smanjila konkurencija između odraslih stabala i stimulirao optimalan rast podmlatka jele.

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SUMMARY

Silver fir is one of the most important tree species not only in Bosnia and Herzegovina, but also in whole of Europe. For natural regeneration of fir the most important factors are site condition, share of fir in stand and tree species composition. The aim of this study was to determine if there are statistically important differences in the number of seedlings and height increment at different competition situations between adult trees. Study area was located at mount Bjelašnica. Data were collected on circular plots with a radius of 12.62m for trees with dbh above 5 cm, and radius 3m for regeneration layer. The competition is expressed using Hegyi competition index, where for the calculation a dominant tree from each quadrant was used. We analysed the total number of fir individuals in regeneration layer and height increment for categories 50-130 cm height and 0.1-5 cm dbh. The results showed that there are no statistically significant differences in the number of for seedlings at different values of the Hegyi index. Statistically significant differences were found in terms of height increment. Height increment decreased with increasing competition between trees.

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ORIGINAL SCIENTIFIC PAPER

Effects of deforestation on rural household income in Oyo state, Nigeria

Utjecaj krčenja šuma na prihode seoskih domaćinstava u državi Oyo, Nigerija

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ABSTRACT

The study examined the effects of deforestation on rural household income in Oyo state, Nigeria. The specific objectives include; identification of the types of livelihood activities; identifying the causes of deforestation; and determining the effects of deforestation on household income. A total of one hundred and eighty (180) rural dwellers were interviewed in 2020. We collected the data through the use of questionnaires and focus group discussions and analysed the data with descriptive statistics and ordinary least square regression (OLS). The result shows that the majority (85.5%) of the respondents were farmers. The livelihood activities employed by the rural households include the combination of farming with any of charcoal production and livestock rearing (50%); charcoal business (33%); the gathering of non-timber forest products (14%); and artisanal work respectively (3.3%). The major causes of deforestation were farm expansion (55%), charcoal use (20.6%), building construction (11.7%), and lumbering (3.9%). The regression analysis revealed that farm expansion, charcoal business, and lumbering were found to significantly increase the household income in the study area. The study thereby recommends the adoption of agroforestry for improved livelihoods and to boost household income, energy, food security and this will also reduce deforestation.

Key words: *deforestation; livelihood; household income; agroforestry; Oyo state*

INTRODUCTION - *Uvod*

Forest resources are a key resource base for economic development with the capacity to provide a perpetual stream of income and products while supporting other economic activities such as fisheries and other agricultural activities through its ecological services and functions which are the mainstay of Nigeria's economy, engaging over 70% of the population (BENSEEDS, 2004; Sambe et al., 2018 & Oyetunji et al., 2020). In Nigeria, forests serve as the home for genetic diversity which provides a rich source of medicinal plants, high-yield foods, and a host for other useful products (Sambe et al., 2018). They supply goods such as timber in addition to non-timber products (food, medicine, raw materials, and fuel e.g. fruits, bamboo, chew stick, game) which benefit most communities to meet the requirements of the rural economy and it supports the livelihood of about 20 million inhabitants, particularly in rural communities (Jatto et al., 2021).

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Deforestation is any activity that hinders the forest ecosystem as a result of agricultural and socio-economic activities to attain development (Ibrahim et al., 2015). It affects the economic activities and threatens the livelihood of forest-dependent people by reducing the supply of forest products (Annan, 2013). Unsustainable wood exploitation, agricultural expansion, bush burning, and infrastructure construction, are generally known to be the major determinants of land degradation and deforestation in Nigeria (Oyebo et al., 2010).

The increasing quest for economic development has led to a speedy degradation of the forests in Nigeria. Forests are depleted annually through industrial, commercial, and other urban-related activities. This is accelerating the degradation and depletion of forest resources and is currently impacting the environment. Deforestation is an ongoing occurrence in Nigeria and it is becoming more evident with increasing population and urbanization (Sambe et al., 2018 & Fasona et al., 2018).

In Nigeria, the rate of deforestation seems to have accelerated in recent years. Deforestation estimates for the country have been put at roughly 285,000 hectares yearly (Sims, 2021). It is expected that if this trend is not addressed, about 50% of the nation's forest land area would be depleted by the next decade. Therefore, deforestation has been considered the main challenge to the forest ecosystem in Nigeria (Sims, 2021 & Fasona et al., 2018).

Nigeria's forest land occupies over nine and a half million ha 10% of the total 92,376,700 ha of land area. The Nigeria forest resources that are located in the lowland and highland forests, plantations, and woodlands contribute 2.5 % to the gross domestic product (GDP) and directly or indirectly employ about two million citizens by supplying poles and fuelwoods with more than 80,000 employees engaged in the wood processing industries (Food and Agricultural Organization (FAO) 2014). Oyebo et al. (2010) indicated that about 9% of forest cover in Nigeria remains intact. Large scale logging and wood extraction activities are also important factors of forest degradation in Nigeria. Particularly, the forest plantation where wood with other forest products are exploited has been put to serious encroachments, degradation of vegetation, and put to use for agriculture, urbanization and for industrial development (FAO, 2014). Nigeria is reported to have the highest rate of deforestation all over the world and it is at 5 % with almost 410,000 ha of total forest land loss yearly between 2010 and 2015. Nigeria is also ranked ninth according to wood extraction with about 73,103m^3 with 87 % used as fuelwood (FAO, 2016).

In Sub-Saharan Africa which includes Nigeria, and in particular, Oyo state, many rural dwellers are still actively involved in deforestation due to their dependence on fuel wood and other forest products as their major energy source and income (Sambe et al., 2018 & Jatto et al., 2021). Their dependence on these products has therefore contributed to the depletion of the country's forest cover. One essential aspect of the knowledge gap is the limited pieces of evidence on the economic implications of deforestation in the state.

However, the inestimable values of forests in promoting sustainable livelihood cannot be over-emphasized; hence the need for an economic assessment of our environment is necessary due to climate change concerns. Given the aforementioned, this study, therefore, is investigating the effects of deforestation on rural household income in Oyo state, Nigeria. The specific objectives are to identify the types of livelihood activities employed by the farming households; identify the causes of deforestation; and determine the effects of deforestation on the household income in the study area.

MATERIAL AND METHODS - *Materijal i metode istraživanja*

Study area

The study was conducted around the forested areas of Oyo Agricultural Development Zones in Oyo state, Nigeria. The state is in the southwestern part of Nigeria and it is situated between latitudes 7°3'0.26" N and 9°11'6.10" N and longitudes 2°42'25.14" E and 4°33'23.84" E (NBS, 2012). The climate is characterized by a dry season between November and March; and a wet season between April and October. The average annual rainfall is 1252.5 mm, while the average temperature ranges from 23.2°C to 31.9 °C, almost throughout the year, with an annual mean relative humidity of 59.1% (NBS, 2012). The total land area of the state as stated by NBS (2012) was 2,650,000 ha and the total land area of forest reserves is 342,461 ha with forest reserves accounting for only 12.92% of the total land area (Alo, 2017). The State consists of four Agricultural Development Programme (ADP) zones that are sub-divided into Local Government Areas or Blocks, namely Shaki with nine LGAs/Blocks, Ogbomoso with five, Oyo with five, and Ibadan/Ibarapa with fourteen (Oyo State Agricultural Development Programme (OYSADEP), 2017).

Data collection procedure

The data for this study was collected in 2020. A total of one hundred and eighty (180) rural dwellers were interviewed through the use of questionnaires and focus group discussions. Information sought included the socio-economic characteristics of the respondents; the types of livelihood activities employed by the respondents; the causes of deforestation; and the effects of deforestation on the income.

Sampling techniques

A 4-staged sampling method was adopted to choose respondents. The first stage involved the random selection of three Agricultural Development Programme (ADP) zones out of the four ADP zones in the state. The zones we selected are Ogbomoso, Saki, and Oyo. In the second stage, we randomly selected one Local Government Area also known as ADP blocks from the selected zones. The selected LGAs were Oriire from Ogbomoso Zone, Saki East from Saki Zone, and Oyo East from Oyo Zone. In the third stage, the study randomly selected six (6) villages from the selected 3 LGAs, eighteen villages were selected all together. In stage four there was a random selection of ten (10) rural families in each of the selected villages, making a total of one hundred and eighty respondents for the study.

Analytical techniques and model specification

The data collected were analyzed with descriptive statistics and multiple regression analysis in other to achieve the specific objectives.

Descriptive statistics

Descriptive statistics such as the frequency tables, mean, percentages as well as graph were used to describe and summarize the socio-economic characteristics of the respondents; the types of livelihood activities employed by the respondents; and the causes of deforestation in the study area.

Multiple regression

The model was used to analyze the effect of deforestation on the income of the respondents. It is represented as:

$$Y = B_0 + B_1X_1 + B_2X_2 + B_3X_3 + B_4X_4 + B_5X_5 + e_i \quad (1)$$

Where:
Y = Income (Naira)
B_0= Intercept
B_1-B_7= Coefficients of the independent variables
X_1= Farm expansion (Hectares)
X_2= Charcoal usage (1= yes; 0, if otherwise)
X_3= Construction (1= yes; 0, if otherwise)
X_4= Urbanization (1= yes; 0, if otherwise)
X_5= Lumbering (1= yes; 0, if otherwise)
e_i= Error term

RESULTS AND DISCUSSION – *Rezultati i diskusija*

Socio-economic characteristics of the respondents

The result in Table 1 revealed that the majority of the respondents (63%) are males while 37% are females. Also, 38.3% of the respondents are within the age bracket 41-50 years while 19.4% represent the 31-40 age bracket and 21.1% represent the 51-60 years bracket while the rest 16.1 covers the 61 and above age group. This suggests that the 41-50 years age group dominates the most economically active group and this age group tends to get actively involved in deforestation. The majority of the respondents are married (75.5%) while 14.4% are single and 8.9% are divorced respectively.

The majority of the respondents are farmers; they cover 85.5% of the respondents while a few of them (14.5%) is engaged in secondary occupation. This was in line with the report of Jatto et al. (2021) in their study. Also, most of the respondents have been involved in farming for a very long time. Those with about 35 years of farming experience accounted for 29.4% of the respondents while 27.8% have 25 years of farming experience.

The result shows that 68% of the respondents have no formal education while 16% of the respondents have primary education. About 7% of the respondents have secondary education while 9% have tertiary education. This shows that the lack of education makes the respondents get actively involved in deforestation since they may not know the adverse effects of deforestation.

The majority of the respondents (53.3%) have an average household size of 6-10 members while 25.5% of the respondents have an average household size of 1-5 members whereas, 15.6% of the respondents have an average household size of 11-15 members while 5.6% have a household size of 16-20 members. The finding was supported by the National Bureau of Statistics (NBS) report in 2012 that an average rural farm household had about six members. The majority of the respondents (67.8%) secured their land through inheritance while 12.8% of them secured their land through rent. Also, 11.1% of the respondents purchased their land while a fraction of the 6.67 got their land through gifts. Hence the reason why the majority of the respondents get involved in deforestation is due to the claim that they have on the land.

Table 1. Socio-economic characteristics of the respondents

Tabela 1. Socio-ekonomske karakteristike ispitanika

Variables	Category	Frequency	Percentage
Gender	Male	113	63
	Female	67	37
Age (years)	<30	9	5
	31-40	35	19.4
	41-50	69	38.3
	51-60	38	21.1
	>60	29	16.1
Marital status	Single	26	14.4
	Married	136	75.5
	Divorced	16	8.9
	Others	2	1.1
Primary occupation	Farming	154	85.5
	Others	26	14.5
Secondary occupation	Trading	70	38.9
	Hunting	43	23.9
	Artisan	23	12.8
	Others	44	24.4
Farming experience (years)	1-10	5	2.78
	11-20	40	22.2
	21-30	50	27.78
	31-40	53	29.4
	41-50	23	12.78
	51-60	9	5
Educational level	No formal	125	68
	Primary	28	16
	Secondary	11	7
	Tertiary	16	9
Household size (number)	1-5	46	25.5
	6-10	96	53.3
	11-15	28	15.6
	16-20	10	5.6
Source of farmland	Inheritance	122	67.8
	Rent	23	12.8
	Outright Purchase	20	11.1
	Gift	12	6.67
	Leasing	3	1.67
Farm size (hectares)	1-10	51	28.3
	11-20	75	41.67
	21-30	47	26.1
	31-40	6	1
	41 and above	1	0.57

Source: Field survey, 2020

The result shows that 41.67% of the respondents have large farmland of between 11-20 hectares while 28.3% have 1-10 hectares of land. Also, 26.1% have between 21-30 hectares of land while a little fraction of 3.3% of the respondents has more than 40 hectares of land. This indicates that the respondents who have larger farmland tend to deforest more.

Types of livelihood activities employed by the respondents in the study area

Figure 1 shows that the respondents are predominantly farmers and are involved in other livelihood activities. About half of the respondents (50%) engaged in more than two livelihood activities like farming, charcoal, and livestock rearing together; 32.8% of them are in the farming and charcoal business; whereas, 13.9% of them are involved in gathering of non-timber forest products (NTFPs) while a small fraction (3.3%) of the respondents are artisans. This result shows that the respondents are forest-dependent. This result indicates that soon, there could be adverse effects on the inhabitants of the study area if proper and adequate measures are not taken to mitigate these activities.

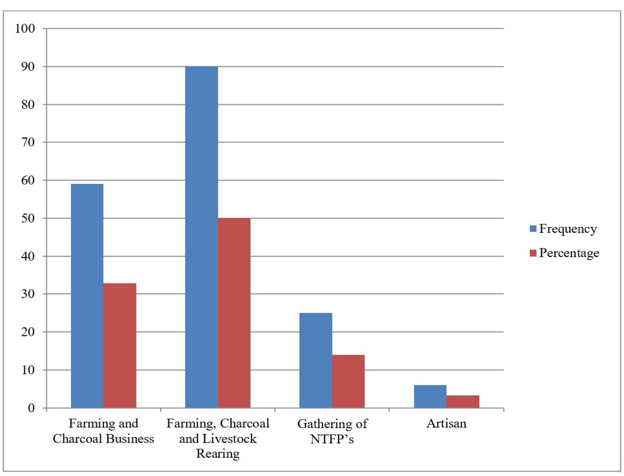

Figure 1: Types of livelihood activities employed by the respondents in the study area
Source: Field survey, 2020

Grafikon 1. Vrsta egzistencije i aktivnosti zaposlenih ispitanika istraživanog područja

Causes of deforestation

Figure 2 reveals that a large percentage of the respondents (55%) deforested because of farm expansion. This is in line with Sambe et al. (2018) that agricultural land expansion is generally viewed as the main source of deforestation contributing to about 60% of the total tropical deforestation. FAO (2016) stated that agricultural expansion is the proximate driver of deforestation worldwide because humankind has greater technological capacity than ever before to bring about rapid land-use change on a very large scale, albeit with differences in geographical distribution. Also, 20.56% of the respondents get involved in charcoal use. This affirms the findings of Oyetunji et al. (2020) that deforestation is usually caused by timber exploitation, charcoal, and firewood consumption and that these factors are exacerbated by population growth. Others include building construction (11.67%), lumbering (8.89%), and 3.89% accounted for other purposes like the production of herbs, hunting, and bush burning.

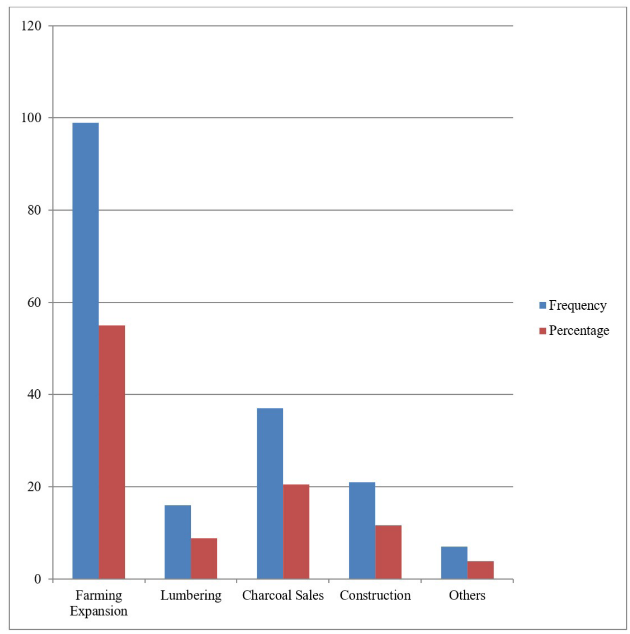

Figure 2: Causes of deforestation in the study area
Source: Field survey, 2020

Grafikon 2. Uzroci krčenja šuma u području istraživanja

The effects of various causes of deforestation on the income of the respondents

Table 2 shows that the R^2 value of the model was 0.4125 implying that the independent variables in the model explained only about 41% of the variability in the household income. From the results of the regression analysis in Table 2, farm expansion, charcoal usage/business, and lumbering are the causes of deforestation affecting the income of the respondents in the study area. This is in line with Osoba et al (2019) that stated that deforestation was identified with the livelihood activities of the people such as hunting, farming and trading of forest products. Farm expansion is positively significant at 5%, that is, the more the people deforest, the more it affects their income. This is in line with Adu et al. (2012) which stated that agriculture contributes to deforestation in the tropics. Also, charcoal usage/business has a positive and significant effect at 5% on the income of the farmers; this implies that most of the respondents majorly deforest for charcoal use asides from the primary reason which is farm expansion. On the other hand, lumbering is positive and significant at 10%. The other variables included in the model were construction and urbanization which were found to be insignificant but positively related to household income.

Table 2: The effects of various causes of deforestation on the income of the respondents

Tabela 2. Utjecaj različitih uzroka krčenja šuma na prihode ispitanika

Variables	Regression coefficients	Standard error
Farming expansion	0.241717	0.536404**
Charcoal sales	0.331831	0.0463517**
Construction	0.0115333	0.061504
Urbanization	0.0178356	0.0618546
Lumbering	0.011741	0.0608963*
_constant	11.13972	0.1084988
R^2	0.4125	

Source: Author's computation, 2021
**5% level of significance; *10% level of significance

CONCLUSION - *Zaključci*

The study concluded that the majority of the rural dwellers are primarily farmers with a long farming experience and they belong to an economically active age. The majority of them are males married with large household size and farmland and have no formal education. Livelihood activities such as combinations of farming, charcoal business, livestock rearing, the gathering of NTFPs, and artisanal work are the major occupations. Farm expansion, charcoal production and usage, building construction, and lumbering are identified to be the major causes of deforestation.

It can be inferred that the effects of deforestation on rural household income produce a positive and significant effect in determining the rural dwellers' income. Farm expansion, charcoal business, and lumbering are the major factors influencing deforestation in the study area. However, the study recommends that the Government and other relevant stakeholders should initiate policies aimed at promoting the adoption of agroforestry technologies to augment their productivity and income thereby increasing their standard of living.

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SAŽETAK

U Nigeriji šume predstavljaju bazu genetske raznolikosti koja pruža bogat izvor ljekovitog bilja, hrane visokog prinosa i drugih korisnih proizvoda. Šume pružaju opskrbu drvetom uz brojne nedrvne šumske proizvode kao što su hrana, lijekovi, sirovine i gorivo, npr. voće, bambus, štapić za žvakanje, divljač od kojih koristi ima većina lokalnih zajednica. Studija je provedena u šumovitim područjima zona poljoprivrednog razvoja u državi Oyo, Nigerija. Za odabir ispitanika usvojena je metoda uzorkovanja u 4 faze. Prva faza uključivala je slučajni odabir tri zone Programa razvoja poljoprivrede (ADP) od četiri ADP zone u državi. Zone koje smo odabrali su Ogbomoso, Saki i Oyo. U drugoj smo fazi nasumično odabrali jedno područje lokalne uprave poznato i kao ADP blokovi iz odabranih zona. U trećoj fazi, studije, nasumično je odabrano šest (6) sela, iz odabrana 3 LGA-a, ukupno je odabrano osamnaest sela. U četvrtoj fazi nasumično je odabrano deset (10) seoskih obitelji u svakom od odabranih sela, što je ukupno činilo sto osamdeset ispitanika za potrebe studije.

Deskriptivna statistika kao što su tablice učestalosti, srednje vrijednosti, postoci kao i grafikoni, korišteni su za opisivanje i sažetak socioekonomskih karakteristika ispitanika, vrste životnih aktivnosti kojima se bave ispitanici, i uzroci krčenja šuma. Usvojena je višestruka regresijska analiza kako bi se analizirao učinak krčenja šuma na prihode ispitanika. Rezultat pokazuje da su većina (85,5%) ispitanika poljoprivrednici. Djelatnosti kojim seoska domaćinstva ostvaruju zaradu uključuju kombinaciju poljoprivrede s proizvodnjom drvenog ugljena i uzgojem stoke (50%), posao s drvenim ugljenom (33%), sakupljanje nedrvnih šumskih proizvoda (14%), odnosno zanatski rad (3,3%). Glavni uzroci krčenja šuma bili su širenje farmi (55%), korištenje drvenog ugljena (20,6%), izgradnja zgrada (11,7%) i sječa drva (3,9%). Regresijskom analizom utvrđeno je da širenje farme, proizvodnja drvenog ugljena i sječa drveta značajno povećavaju dohodak domaćinstva u području istraživanja. Može se zaključiti da učinci krčenja šuma na dohodak ruralnih domaćinstava imaju pozitivan i značajan učinak u određivanju prihoda ruralnih stanovnika. Širenje farmi, proizvodnja drvenog ugljena i sječa glavni su faktori koji utiču na krčenje šuma u području istraživanja.

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ORIGINAL SCIENTIFIC PAPER

Balkan endemic vascular flora of the Konjuh Mountain

Balkanska endemska vaskularna flora planine Konjuh

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ABSTRACT

This paper presents data on the diversity and distribution of Balkan endemic vascular plants on Konjuh Mountain in northeastern Bosnia and Herzegovina. Konjuh is characterized by geological heterogeneity and a significant proportion of ophiolitic substrate, which supports the development of endemic-relict serpentinophytes. A total of 31 endemic and four subendemic taxa were recorded in the surveyed area. Among these, *Caryophyllaceae*, with five recorded endemic taxa, is the most abundant family. The analysis of life forms and chorological spectra showed a dominance of hemicryptophytes and taxa from the South European and Mediterranean-Sub-Mediterranean chorological groups. The majority of endemic and relict taxa in the surveyed area are serpentinophytes. A total of 18 recorded taxa are listed as threatened according to the Red List of Flora of the Federation of Bosnia and Herzegovina. The species findings are presented with a distribution map. The distribution range of endemic and endangered taxa in Konjuh extends beyond the protected area. The results provide a list of locations of particular interest for further research and potential protection due to the diversity of endemic taxa.

Key words: *endemics, serpentinophytes, threatened taxa, flora, Konjuh*

INTRODUCTION – *Uvod*

The term "endemism" can be defined in many ways, and in most cases, it refers to the limitation of a species' range to a geographical area, type of ecosystem or habitat, biogeographical region, or a specific country (Nikolić et al., 2015). In the biological context, endemics are taxonomic units (populations, subspecies, species, genera) whose distribution is restricted to a certain area (Šilić, 1990). Depending on the size of their range, endemics can be divided into two groups: subendemic, or endemics in a broader sense, which inhabit larger geographical areas (e.g., the entire Balkan Peninsula), and steno-endemics, or endemics in the narrower sense, which are distributed in smaller areas (individual mountains, canyons, island groups, a single country). Additionally, the term "local endemics" is used to describe taxa limited to a narrow area of up to several hectares. The definition of Balkan endemic species has remained unchanged since Turill (1929), who defined them as species with a range limited to the Balkan Peninsula (Tomović et al., 2014). According to the available data, the vascular flora of the Balkan Peninsula contains approximately 8000 taxa, including 2600-2700 endemic taxa at the species or subspecies level (Stevanović, 2005).

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The unique processes of forming the geological base, soil types, relief, ecoclimate, and water regime in the past have led to the development of a unique flora in the Dinarides of Bosnia and Herzegovina. It is characterized by the presence of numerous paleo- and neo-endemics, as well as tertiary and glacial relics that survived in refugia such as gorges, canyons, and mountain cirques. The first National report for the Convention on Biodiversity (Redžić et al., 2008) states that the flora of Bosnia and Herzegovina contains 450 endemics, which is one-tenth of the total number of vascular taxa registered in the country. According to Lubarda et al. (2014; 2019), the flora of Bosnia and Herzegovina contains 309 Balkan endemic taxa at the species and subspecies level, classified into five chorological groups.

The parts of Konjuh Mountain consist of serpentine (ophiolitic, ultramafic) rocks, characterized by a low silicon content (less than 45%), calcium deficiency, high concentrations of aluminum, iron, magnesium, nickel, cobalt, and chromium, and a low content of plant nutrients (Pustahija, 2011). The serpentine area is rich in basiphilous-calcifugal plants. According to Stevanović et al. (2003), 15–16% of Balkan endemics have been recorded on serpentine, while 123 (6%) endemic taxa are obligate serpentinophytes.

The first extensive floristic research of Konjuh was conducted in the western part of the mountain by Ritter-Studnička (1958; 1963; 1970) as part of a broader study of the serpentine flora and continued for the purpose of an exhaustive study of genome size in plants growing on serpentine (Pustahija et al., 2013). The diversity of algae and aquatic plants in crenic communities of the Konjuh Mountain was described by Kamberović (2015; 2020) and Kamberović et al. (2019). Several endangered and endemic taxa were listed in the paper on the diversity of Paučko Lake (Kamberović et al., 2020). Recent publications include remarks on the distribution of endemic plants *Polygonum albanicum* (Maslo and Šarić, 2021) and *Euphorbia serpentini* (Maslo et al., 2022), as well as data on the distribution of the threatened species *Adenophora liliifolia* (Ballian and Šarić, 2015).

A part of Konjuh Mountain is legally protected as a fifth-category protected area - a Protected Landscape, and recent biological surveys have mainly focused on this area. A study conducted by a group of authors contracted by "Enova" in 2017, in order to create a baseline of the state of biodiversity of the Konjuh Protected Landscape, lists a total of 11 endemics and 10 sub-endemics out of a total of 326 plant taxa registered in the area of the Protected Landscape. Additionally, a study on species and ecosystem diversity in the Protected Landscape Konjuh, published as part of a project realized by the non-governmental organization CISP (2019), lists about 500 plant taxa but excludes the endemism analysis.

The aim of this paper is to survey and present qualitative data on the taxonomy, distribution, chorological groups, floristic elements, and conservation status of Balkan endemic plant taxa in the entire area of Konjuh Mountain, including parts outside of the present Protected Landscape for which recent data were not available.

MATERIALS AND METHODS – *Materijal i metode*

Study area

The Konjuh Mountain is part of the central Dinarides. It is located between northeastern and central Bosnia and is topographically classified as a hilly-mountainous area, with absolute altitudes ranging from 300 to 1326 m a.s.l. (Ristić et al., 1967). The geological structure consists of a complex of magmatic, metamorphic, and sedimentary formations. Konjuh is part of a large ultrabasic massif, the Krivaja-Konjuh ophiolite complex, which is one of the largest complexes in the Dinaric ophiolite zone. Ultramafic rocks (ultrabasic, serpentine, peridotite) predominate in the geological structure of Konjuh Mountain, especially in the west and northwest. The central parts of the mountain consist of igneous rocks, mostly diabase, and the eastern part is mostly composed of sedimentary rocks of Middle Triassic limestone. An undissociated formation of ophiolitic mélange is found along the eastern and southern parts of the Konjuh peridotite-serpentine massif. It includes various clays (sometimes schistose), sandstones, less often conglomerates, marls, marly limestones, and cherts (Babajić, 2009).

Automorphic soils, namely eutric cambisols, are the most widespread soil types in the area of Konjuh Mountain. Ranker-cambisol and cambisol-luvisol layers on peridotites and serpentinites, and distric cambisol on acid silicate rocks, are also common, while chalcocambisols are far less represented. The area of Konjuh is situated in a moderately continental climate zone and is characterized by harsh winters and warm summers, with a continental pluviometrical precipitation regime (Kudumović Dostović et al., 2019).

According to CISP (2019), the vegetation types present in Konjuh Mountain include acidophilic beech forests (*Luzulo-Fagion sylvaticae*), Illyrian beech forests (*Aremonio-Fagion*), black pine and Scots pine forests on serpentine and peridotite (*Erico-Fraxinion orni*) with relict associations *Seslerio serbicae-Pinetum nigrae* and *Erico-Pinetum sylvestris*, acidophilic mountain spruce forests (*Vaccinio-Picenion*) including *Luzulo sylvaticae-Piceetum* association, oak-hornbeam forests (*Erythronio-Carpinion betuli* and *Quercion petraeae*) with *Epimedio-Carpinetum betuli* and *Erico-Quercetum petraeae* associations, alluvial forests on fluvisols (*Alnion glutinosae*), serpentine rocky grassland of the order *Halacsyetalia sendtneri*, mountain and lowland hay meadows, limestone and silicate rocks with chasmophytic vegetation, and partially developed limestone screes. The flora and vegetation on the peridotites and serpentinites of Konjuh Mountain have a tertiary-relict character and have been preserved in refugium-type habitats, especially in the ecosystems of black pine and Scots pine forests, serpentine rocky grasslands, and rock crevices. Kamberović (2015) also described the *Platyhypnidion rusciformis*, *Cratoneurion commutati*, and *Caricion remotae* alliances in spring ecosystems on the Konjuh Mountain.

The data on the distribution of endemic vascular flora in Konjuh were collected from 2002 to 2022. The survey covered the wider area of Konjuh Mountain, which stretches between Olovo, Kladanj, Banovići and Živinice basins and the Krivaja River (Figure 1), and focused on serpentine habitats in Grabovica, Olovo, Župeljeva, Velika Maoča, Velika and Mala Ribnica, Mačkovac, Varda, Zelenboj, Zidine, Veliki Konjuh, Mali Konjuh, and the watersheds of Drinjača. The limestone habitats around Olovo, Crni Potok, Kamensko-Sokolina, Brateljevići, Tuholj, Krabanja, Djedinska planina, and Mačkovac were also surveyed.

Figure 1. The study area of Konjuh Mountain

Slika 1. Područje istraživanja Konjuh planine

Species identification and data analysis

The plant taxa were identified according to Tutin et al. (1964-1993) and Nikolić (2020a; 2020b). Taxonomic status was determined according to the Euro+Med database (http://ww2.bgbm.org/EuroPlusMed/). The endemic status was assigned based on the lists of endemic taxa (Šilić, 1990; Lubarda et al., 2014; Lubarda, 2019). The assessment of the conservation status was done according to the Red List of wild species and subspecies of plants, animals, and fungi of the Federation of Bosnia and Herzegovina (Official Gazette of the Federation of Bosnia and Herzegovina, 07/14; Đug et al., 2013), and the IUCN Red List of Threatened Species (IUCN, 2022). The analysis of the presence of protected taxa was done according to the list from the Rulebook on Protection Measures for Strictly Protected Species and Subspecies (Official Gazette of the Federation of Bosnia and Herzegovina, 21/2020). The relict status was assigned according to Stevanović et al. (2003). The data on floral elements and chorological groups were determined according to Lubarda et al. (2014), and the data on life forms according to Raunkiaer (1934) from Mueller-Dombois & Ellenberg (1974) and Stevanović (1992). Digital photographs were taken for each taxon in the field.

The distribution of the taxa is presented on the map using a standard UTM 10×10 km grid based on the Military Grid Reference System (MGRS) projection (Lampinen, 2001) in zones 33T and 34T. The distribution map of endemic taxa was created using QGIS software version 3.4, based on OSM (https://www.openstreetmap.org).

RESULTS AND DISCUSSION – *Rezultati i diskusija*

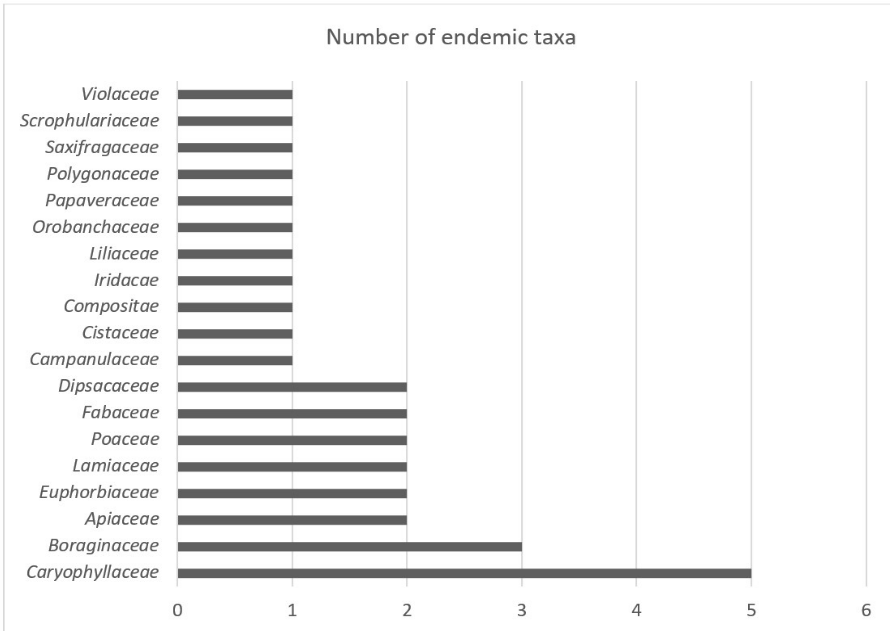
A total of 31 endemic plant taxa, classified into 19 families and 27 genera, were recorded in the area of the Konjuh Mountain (Table 1). This number represents 10% of the total number of plant endemics listed by Lubarda et al. (2019) specific to Bosnia and Herzegovina. Additionally, 4 subendemic taxa were identified: *Dianthus giganteus* D'Urv subsp. *croaticus* (Borbás) Tutin, *Dianthus petraeus* Waldst. et Kit. subsp. petraeus, *Scabiosa cinerea* Lam. subsp. *cinerea*, and *Pilosella pavichii* (Heuff.) Arv.-Touv (synonym of *Hieracium pavichii* Heuff.). The distribution of these taxa extends across a wider area of South-Eastern Europe and therefore they are not included in the list. *Caryophyllaceae* is the most abundant family with 5 taxa, followed by *Boraginaceae* with 3 taxa (Graph 1). Genera *Sesleria, Euphorbia, Knautia*, and *Cerastium* are represented by two taxa each, while all other genera are represented by only one taxon.

Table 1. List of the Balkan endemic taxa of the vascular flora of the Konjuh Mountain

Tabela 1. Popis balkanskih endemskih taksona vaskularne flore planine

Taxon	Chorological group	Chorological subgroup	Floral element	Life form*	Threatened status*	Conservation status*
Apiaceae						
1. *Athamanta turbith* (L.) Brot. subsp. *haynaldii* (Borbás et Uechtr.) Tutin	SEM	Dinar-Balk	Dinar(W-E)-Balk(sc-pind(N))	Ch	**EN**	
2. *Peucedanum aegopodioides* (Boiss.) Vandas	CE	Illyr-Balk	Illyr(C-E)-Balk(sc-pind(N-C)-moes(W-C)	H		
Boraginaceae						
3. *Halacsya sendtneri* (Boiss.) Dörfler.	MED-SUBMED	Balk(subcont)	Illyr(C-E)-Balk(sc-pind(N-C))	Ch	NT	
4. *Myosotis suaveolens* Willd.	CEM	Dinar-Balk	Dinar(W-E)-Balk(sc-pind(N-C)-moes(W-E))	H		
5. *Onosma stellulata* Waldst. et Kit.	MED-SUBMED	Balk(subcont)	Illyr(W-E)-Balk(sc-pind(N))	Ch	**LC**	
Campanulaceae						
6. *Edraianthus graminifolius* (L.) A.DC.	SEM	Dinar-Balk	Dinar(C-E)-Balk(moes(W))	Ch	NT	
Caryophyllaceae						
7. *Cerastium malyi* (Georgiev) Niketić subsp. *serpentinii* (Novak) Niketić.	SEM	Dinar	Dinar(C-E)	Ch		
8. *Cerastium rectum* Friv.	SEM	Dinar-Balk	Dinar(C-E)-Balk(sc-pind(N)-moes(W-E))	T		
9. *Gypsophila spergulifolia Griseb.* var. *serbica* Vis. & Pančić	MED-SUBMED	Balk(subcont)	Illyr(C-E)-Balk(sc-pind(N-C))	Ch		
10. *Heliosperma pusillum* subsp. *monachorum* (Vis. & Pančić) Niketić & Stevanović	SEM	Dinar	Dinar(C-E)	Ch	DD	
11. *Minuartia bosniaca* (G. Beck) K. Maly	SEM	Dinar-Balk	Dinar(C-E)-Balk(sc-pind(N)-moes(W))	H	VU	
Cistaceae						
12. *Fumana bonapartei* Maire & Petitm.	MED-SUBMED	Balk(subcont)	Illyr(C-E)-Balk(sc-pind(N-C))	Ch	**CR**	**SP**
Compositae						
13. *Centaurea nigrescens* subsp. *smoliensis* (Hayek) Dostal.	CE	Illyr	Illyr(C-E)	H	VU	
Dipsacaceae						
14. *Knautia sarajevensis* (Beck) Szabó	CEM	Dinar	Dinar(C-E)	H	LC	
15. *Knautia dinarica* (Murb.) Borbás subsp. *dinarica*	CE	Illyr	Illyr(C-E)	H	LC	
Euphorbiaceae						
16. *Euphorbia gregersenii* K.Maly.	CE	Illyr	Illyr(C-E)	H	NT	
17. *Euphorbia serpentini* Novák	SEM	Dinar		H		

Fabaceae						
18. *Cytisus austriacus* var. *maezius* K.Maly	PONT	Illyr	Illyr(C-E)	P		
19. *Trifolium dalmaticum* Vis.	MED-SUBMED	Balk(med-submed subcont)	Adriat(N-S)-Ion(N-S)-Illyr(W-E)-Balk(sc-pind(N-S)-moes(W-E))	T		
Iridaceae						
20. *Iris reichenbachii* Heuff. var. *bosniaca* G. Beck	SEM	Dinar	Dinar(C-E)	G	LC	
Lamiaceae						
21. *Stachys recta* subsp. *baldaccii* (K. Malý) Hayek	SEM	Dinar	Dinar(W-E)	H	**CR**	
22. *Thymus praecox* subsp. *jankae* (Čelak.) Jalas	MED-SUBMED	Balk(subcont)	Illyr(W-E)-Balk(sc-pind(N-C)-moes(W))	Ch		
Liliaceae						
23. *Lilium carniolicum* Bernh. ex Koch subsp. *bosniacum* (Beck) Asch.et Graebn.	CEM	Dinar-Balk	Dinar(C-E)-Balk(sc-pind(N-C))	G	DD	
Orobanchaceae						
24. *Melampyrum hoermannianum* K. Maly	CE	Illyr	Illyr(C-E)	T	DD	
Papaveraceae						
25. *Pseudofumaria alba* subsp. *leiosperma* (P. Conrath) Lidén	MED-SUBMED	Balk(subcont)	IllyrW-E)-Balk(sc-pind (N)	H	**EN**	**P**
Poaceae						
26. *Sesleria latifolia* (Adamovic) Degen. var. *serpentini-ca* Deyl.	SEM	Dinar-Balk	Dinar(C-E)-Balk(sc-pind(N-C)-moes(W-E))	H		
27. *Sesleria serbica* (Adamović) Ujhelyi	SEM	Dinar	Dinar(C-E)	H		
Polygonaceae						
28. *Polygonum albanicum* Jáv.	PONT	Illyr-Balk	Illyr(C-E)-Balk(sc-pind(N-C))	T		
Saxifragaceae						
29. *Saxifraga blavii* (Engler) Beck	CEM	Dinar-Balk	Dinar(W-E)-Balk(sc-pind(N))	H		
Scrophulariaceae						
30. *Scrophularia canina* L. subsp. *tristis* (K. Maly) Nikolic	MED-SUBMED	Balk(subcont)	Illyr(C-E)-Balk(sc-pind(N))	T-H	**EN**	**P**
Violaceae						
31. *Viola beckiana* Fiala ex Beck.	MED-SUBMED	Balk(subcont)	Illyr(C)	H	NT	



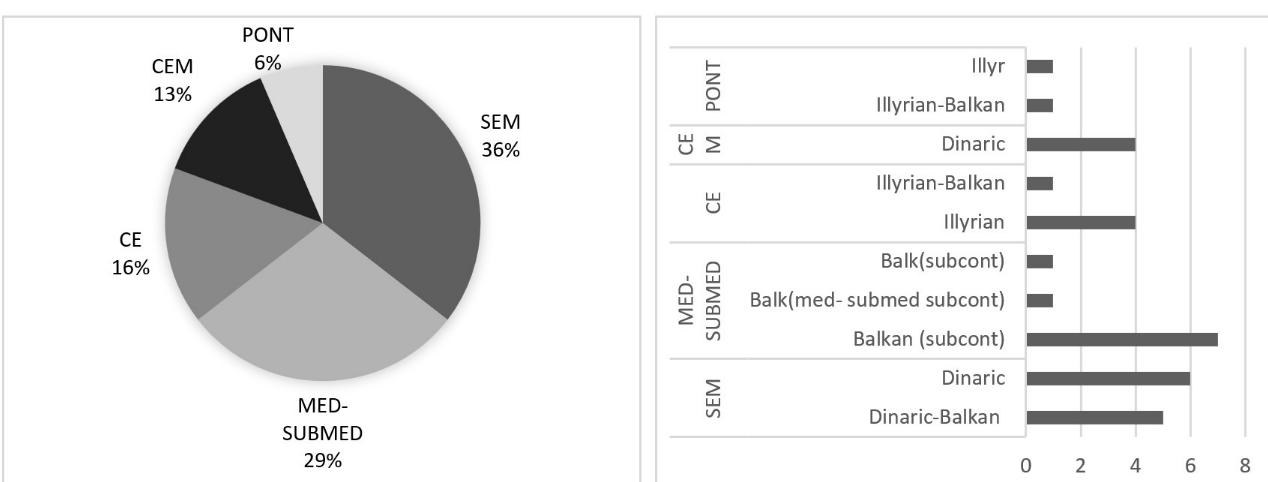
Graph 1. Endemic taxa richness at the family level

Grafikon 1. Bogatstvo endemskih taksona na nivou familije

* SEM - South European mountainous, MED-SUBMED - Mediterranean-Submediterranean, CEM - Central European mountainous; CE - Central European, PONT - Pontic, Chamephyte (Ch), Hemicryprophyte (H), Geophyte (G), Therophyte (T); CR - critically endangered, EN - endangered, NT - near threatened, LC - least concern, DD - data deficient; Conservation status: SP- strictly protected taxa, P – protected taxa.

The endemic taxa of the Konjuh Mountain were recorded in MGRS quadrants 100×100 BP, CP, BQ, and CQ (Figure 2). Most taxa were found in quadrants BQ90, CQOO, CQ01, and BQ91.

The highest number of endemic taxa recorded in the Konjuh Mountain are serpentinophytes. Obligate serpentine endemics in the studied area include *Halacsya sendtneri*, *Fumana bonapartei*, *Gypsophila spergulifolia* var. *serbica*, *Polygonum albanicum*, *Stachys recta* subsp. *baldacci*, *Scrophularia canina* subsp. *tristis*, *Sesleria serbica*, *Euphorbia gregersenii*, *Centaurea nigrescens* subsp. *smoliensis*, and *Euphorbia serpentini*. Within the boundaries of the



a) b)

Graph 2. Spectrum of chorological groups (a) and subgroups (b) of the Balkan endemic vascular flora of Konjuh Mountain: SEM - South European mountainous, MED-SUBMED - Mediterranean-Sub-Mediterranean, CEM - Central European mountainous; CE - Central European, PONT - Pontic.

Grafikon 2. Spektar horoloških grupa (a) i podgrupa (b) balkanske endemske vaskularne flore planine Konjuh. SEM – južno evropsko planinska, MED-SUBMED – mediteransko-submediteranska, CEM – centralno-evropsko planinska, CE – centralno-evropska, PONT- pontska.

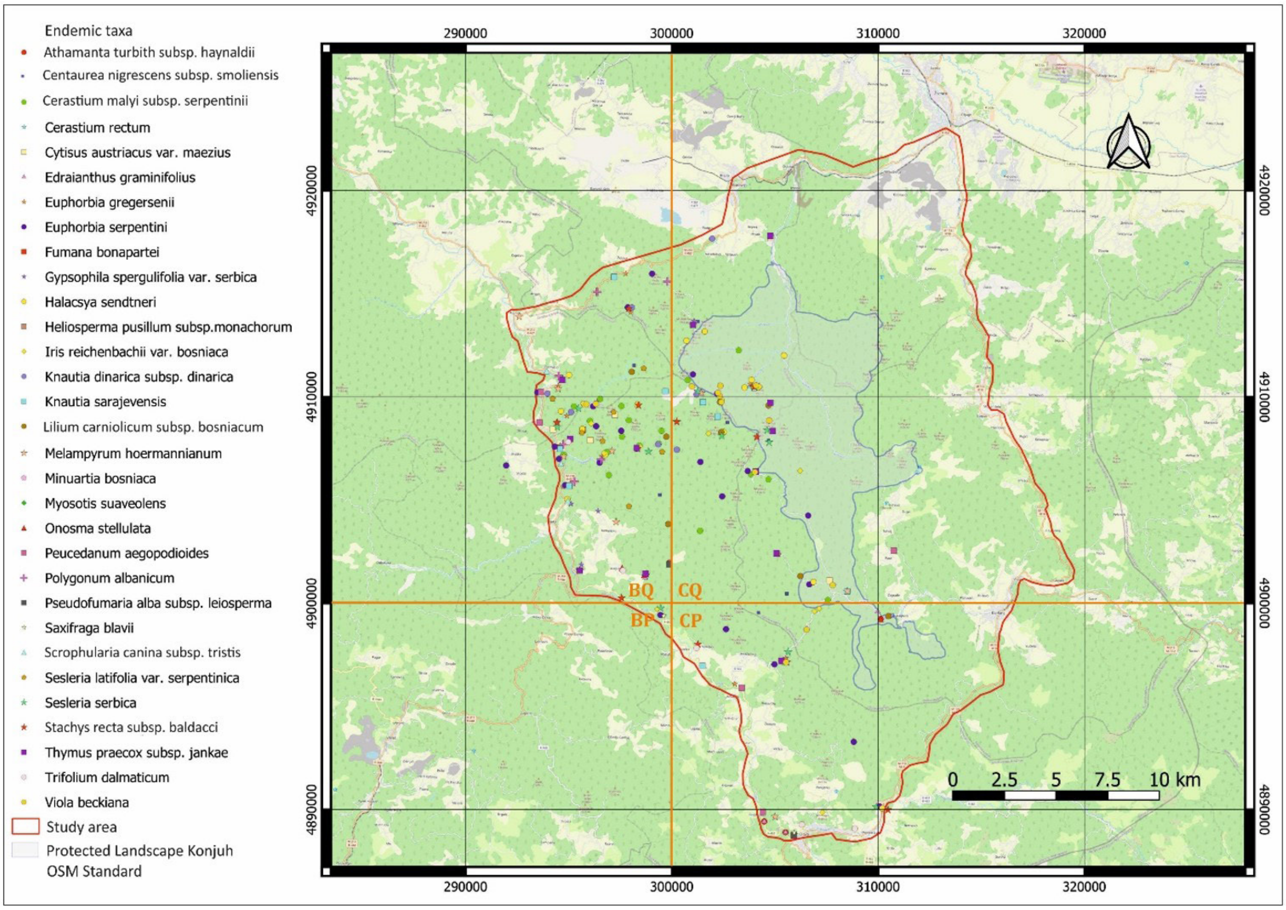


Figure 2. The distribution of endemic taxa on the Konjuh Mountain per MGRS 10×10 km square

Slika 2. Distribucija endemskih taksona na planini Konjuh po MRGR kvadrantima 10×10 km

Konjuh Protected Landscape, the locations of Varda, Zidine, Zelenboj, Mali Konjuh, Miljevica, and Borovnica are of special interest for stricter preservation due to the richness of endemic flora. A large number of endemic taxa were registered outside the boundaries of the Konjuh Protected Landscape, which administratively belongs to the Zenica-Doboj canton. The locations of Zerinska kosa, Modra ploča, Mladoševac, Smolin, the catchment area of the upper reaches of Župeljeva, and Mala Maoča are of particular interest for more detailed ecosystem research and further protection of relict serpentine endemic taxa.

In comparison to the above-mentioned taxa, a lower number of endemic taxa occur exclusively on limestone rocks: *Athamanta turbith* subsp. *haynaldii*, *Pseudofumaria alba* subsp. *leiosperma*, *Edraianthus graminifolius*, *Minuartia bosniaca*, and *Onosma stellulata*. The locations of Sokolina, Kamensko, Magulica, Olovski krševi, and the limestone area around the Drinjača river are important for detailed research and potential protection of habitats for carbophilic endemic taxa of the Konjuh mountain.

The chorological analysis of the Balkan endemics on the Konjuh Mountain reveals the dominance of Dinaric and Dinaric-Balkan floral elements, which belong to the South European Mountain (SEM) and Mediterranean-Sub-Mediterranean chorological groups (MED-SUBMED) (Graphs 2a and 2b).

The South European Mountain chorological group is the most numerous group of endemics in Bosnia and Herzegovina and neighboring Serbia (Tomović et al., 2014). The related taxa are widespread in the mountains of southern Europe. The representatives of this chorological group in the flora of Konjuh Mountain include *Cerastium malyi* subsp. *serpentinii, Cerastium rectum*, *Edraianthus graminifolius*, *Euphorbia serpentini*, *Iris reichenbachii* var. *bosniaca*, *Heliosperma pusillum* subsp. *monachorum*, *Sesleria latifolia* var. *serpentinica*, and *S. serbica* (*Figure 3*).

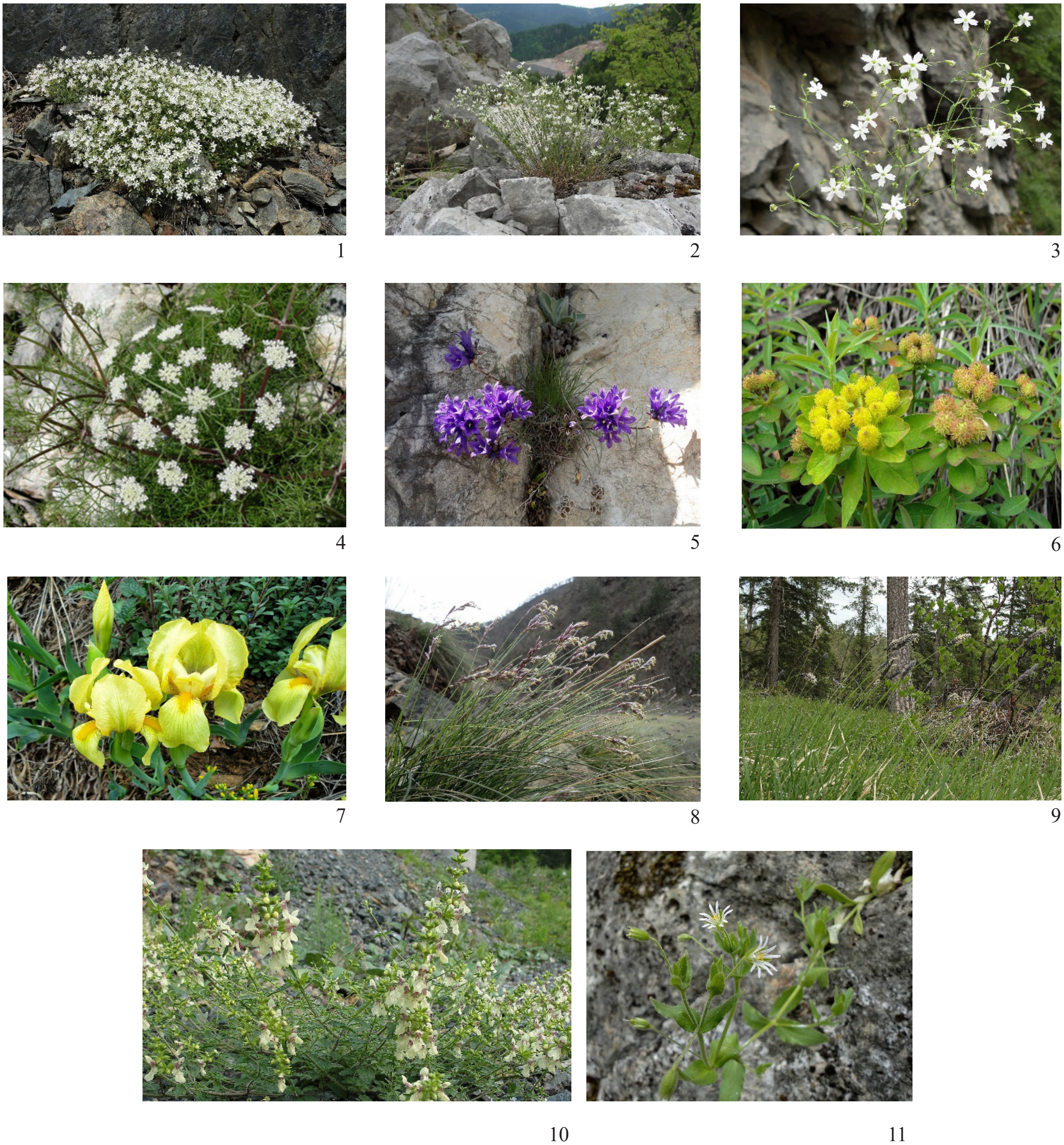


Figure 3. Endemic taxa of the Konjuh Mountain from the SEM chorological group: 1 *Cerastium malyi* subsp. *serpentinii*, 2 *Minuartia bosniaca*, 3 *Heliosperma pusillum* subsp. *monachorum*, 4 *Athamanta turbith* subsp. *haynaldii*, 5 *Edraianthus graminifolius*, 6 *Euphorbia serpentini*, 7 *Iris reichenbachii* var. *bosniaca*, 8 *Sesleria serbica*, 9 *Sesleria latifolia* var. *serpentinica*, 10 *Stachys recta* subsp. *baldacci*, 11 *Cerastium rectum* (Photos: Š. Šarić)

Slika 3. Predstavnici endemskih biljnih taksona planine Konjuh iz SEM horološke grupe: 1. Cerastium malyi subsp. serpentinii, 2. Minuartia bosniaca, 3. Heliosperma pusillum subsp. monachorum, 4. Athamanta turbith subsp. haynaldii, 5. Edraianthus graminifolius, 6. Euphorbia serpentini, 7. Iris reichenbachii var. bosniaca, 8. Sesleria serbica, 9. Sesleria latifolia var. serpentinica, 10. Stachys recta subsp. baldacci, 11. Cerastium rectum (Foto: Š. Šarić)

The second most numerous chorological group is the Mediterranean-Sub-Mediterranean (MED-SMED), with the Balkan subcontinental subgroup, which includes old Mediterranean taxa typical for the continental thermophilic habitats on limestone or serpentine of the Balkan Peninsula. Most taxa of this chorological group were registered in serpentine habitats at Konjuh: *Fumana bonapartei*, *Gypsophila spergulifolia*, *Halacsya sendtneri*, *Scrophularia canina* subsp. *tristis*, *Thymus praecox* subsp. *jankae*, *Trifolium dalmaticum*, and *Viola beckiana* (Figure 4). The high share of SEM and MED/SMED chorological groups in Konjuh and northeastern Bosnia can be explained by the fact that serpentine habitats are scarce in water and provide conditions for the growth of thermophilic plant taxa.

The Central-European (CE) group with Illyrian and Illyrian-Balkan subgroups, and the Central-European Mountain group (CEM) with the Dinaric subgroup, are each represented by four taxa. Relatives of the CEM group are spread across the mountains of Central Europe, the Alps, and a smaller part of the Carpathians. The taxa from this group registered at Konjuh Mountain include *Knautia sarajevensis*, *Lilium carniolicum* subsp. *bosniacum*, *Myosotis suaveolens*, and *Saxifraga blavii*. The Central European chorological group consists of species distributed in forest and meadow habitats of hilly and mountainous continental areas. In Konjuh, this group mostly consists of taxa from the Illyrian chorological subgroup: *Euphorbia gregersenii*, *Centaurea nigrescens* subsp. *smoliensis, Melampyrum hoermannianum*, *Knautia dinarica* subsp. *dinarica*, and *Peucedanum aegopodioides*. Two

Figure 4. Endemic taxa of the Konjuh Mountain of the MED-SMED chorological group: 1 *Halacsya sendtneri*, 2 *Fumana bonapartei*, 3 *Scrophularia canina* subsp. *tristis*, 4 *Viola beckiana*, 5 *Thymus praecox* subsp. *jankae*, 6 *Gypsophila spergulifolia*, 7 *Onosma stellulata*, 8 *Pseudofumaria alba* subsp. *leiosperma*, 9 *Trifolium dalmaticum* (Photos: Š. Šarić)

Slika 4. Predstavnici endemskih biljnih taksona planine Konjuh iz MED-SMED horološke grupe: 1. Halacsya sendtneri, 2. Fumana bonapartei, 3. Scrophularia canina L. subsp. tristis, 4. Viola beckiana, 5. Thymus praecox subsp. jankae, 6. Gypsophila spergulifolia, 7. Onosma stellulata, 8. Pseudofumaria alba subsp. leiosperma, 9. Trifolium dalmaticum (Foto: Š. Šarić)

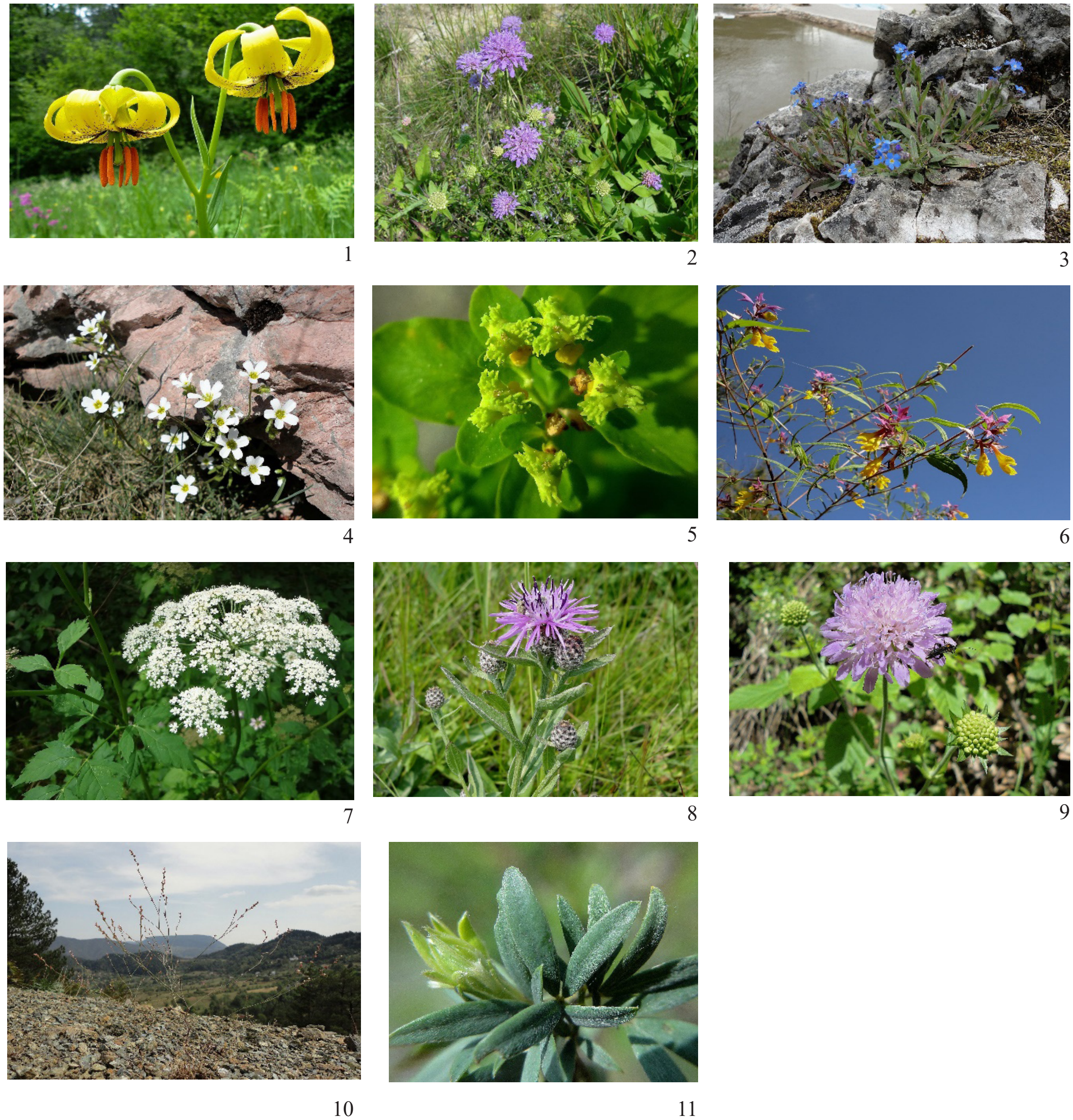
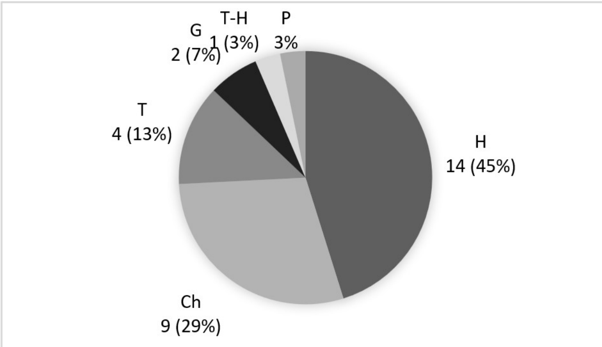


Figure 5. Endemic taxa of the Konjuh Mountain from the CEM, CE and PONT chorological groups: 1 *Lilium carniolicum* subsp. *bosniacum*, 2 *Knautia sarajevensis*, 3 *Myosotis suaveolens*, 4 *Saxifraga blavii*, 5 *Euphorbia gregersenii*, 6 *Melampyrum hoermannianum*, 7 *Peucedanum aegopodioides*, 8 *Centaurea nigrescens* subsp. *smoliensis*, 9 *Knautia dinarica* subsp. *dinarica*, *10 Polygonum albanicum*, *11 Cytisus austriacus* var. *maezius* (Photos: Š. Šarić)

Slika 5. Predstavnici endemskih biljnih taksona planine Konjuh iz CEM, CE i PONT horoloških grupa: 1. Lilium carniolicum subsp. bosniacum, 2. Knautia sarajevensis, 3. Myosotis suaveolens, 4. Saxifraga blavii, 5. Euphorbia gregersenii, 6. Melampyrum hoermannianum, 7. Peucedanum aegopodioides, 8. Centaurea nigrescens subsp. smoliensis, 9. Knautia dinarica subsp. dinarica, 10. Polygonum albanicum, 11. Cytisus austriacus var. *maezius (Foto: Š. Šarić)*

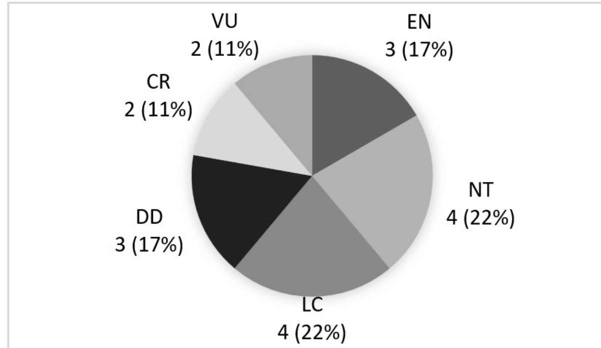
taxa (*Polygonum albanicum* and *Cytisus austriacus* var. *maezius*) belong to the Pontic chorological group and inhabit extremely thermophilic serpentine habitats.

The life form analysis of endemic plant taxa shows the domination of hemicryptophytes (14 taxa, 45%) and chamaephytes (9 taxa, 29%), which is in accordance with the data on the endemic flora of Central Serbia, Kosovo, and Montenegro (Tomović et al., 2014; Vuksanović et al., 2016; Halilaj et al., 2021). Therophytes are more numerous than geophytes, while endemic phanerophytes include only one taxon - *Cytisus austriacus* var. *maezius* (Graph 3).



Graph 3. The life form spectrum of the Balkan endemic flora of the Konjuh Mountain: Ch – chamaephytes; H – hemicryptophytes; G – geophytes; T – therophytes; T-H – therophytes and hemicryptophytes

Grafikon 3. Spektar životnih formi balkanske endemske flore Konjuh planine: Ch – hamefite; H – hemikriptofite; G – geofite; T – terofite; T-H – terofite i hemikriptofite.



Graph 4. The spectrum of threatened status of endemic taxa of Konjuh Mountain: CR – critically endangered, EN – endangered, NT – near threatened, VU – vulnerable, LC – least concern, DD – data deficient

Grafikon 4. Spektar statusa ugroženosti endemskih taksona planine Konjuh: CR – kritično ugrožene, EN – ugrožene, NT – gotovo ugrožene, VU – ranjive, LC – najmanje zabrinjavajuće, DD – nedovoljno podataka

The analysis of the threatened status of endemic taxa of Konjuh indicates that 18 taxa are classified in one of the categories according to the Red List of Flora of the Federation of Bosnia and Herzegovina (Graph 4). Two taxa (*Fumana bonapartei* and *Stachys recta* subsp. *baldacci*) are critically endangered (CR). *F. bonapartei* is an endemic relict, a strictly protected species in the Federation of Bosnia and Herzegovina, and an obligate serpentinophyte found in extremely thermophilic, rocky steppic grasslands over shallow soils on ultramafic bedrocks. This species was recorded in only a few locations in previous research in Bosnia and Herzegovina, mostly inhabiting the serpentines around Višegrad and Rudo Mountain (Ritter-Studnička, 1970). The small populations were observed in only two locations on Konjuh Mt: Varda and Zerinska kosa, implying the need for stricter protection measures. On the contrary, *Stachys recta* subsp. *baldacci* has been observed in several locations on Konjuh Mt.

Three endemic taxa present at Konjuh are listed as endangered (EN): *Athamanta turbith* subsp. *haynaldii*, *Pseudofumaria alba* subsp. *acaulis*, and *Scrophularia canina* subsp. *tristis*. The last two taxa are also protected in the Federation of Bosnia and Herzegovina. *A. turbith* ssp. *haynaldii* has been found on three locations (Olovski krševi, Brateljevići i Sokolina), whilst *P. alba* subsp. *acaulis* inhabits two locations Olovo and Sokolina. Both species are associated with exposed carbonate habitats. *S. canina* subsp. *tristis* has been identified exclusively in serpentine habitats in several locations (Varda, Careva Ćuprija, Buk, Grgići).

The endemic plant richness of Konjuh, which includes 31 endemic taxa and four subendemic taxa, is not negligible in comparison with the high Dinaric mountains (Bjelčić et al., 1969; Bjelčić & Šilić, 1971; Lakušić & Redžić, 1989; Šilić & Abadžić, 1986, 1991; Stevanović, 1996), considering the overall height of the mountain and its geographical position. After analyzing and synthesizing the previous results on Balkan endemic flora in Bosnia and Herzegovina, published by numerous botanists over the last 150 years, Lubarda et al. (2014) concluded that the greatest diversity of endemic plant species is recorded in the Herzegovinian mountains (Prenj, Čvrsnica, Čabulja), where about 125 taxa are present, followed by the mountains of Bjelašnica, Treskavica, Ivan, and the canyon of the Rakitnica river (109 taxa), and the mountains on the border with Montenegro, Maglić and Volujak, with the Sutjeska river canyon (99 taxa). The richest endemic mountain flora was recorded on Prenj (99 taxa), Čvrsnica (78), Orjen (74), Velež (70), Treskavica (63), Maglić (58), and Dinara (52). The largest number of endemic species of the Konjuh Mountain is found on the ophiolitic substrate in rocky steppic grasslands over shallow soils on ultramafic bedrock, vegetation order *Halacsyetalia sendtneri*, or relic-refuge black pine and Scots pine forests of the alliance *Erico-Fraxinion orni*, which are of significant natural and conservation value in this area. Serpentine endemics participate with 335-350 endemic taxa (or 15-16%) in the Balkan endemic flora (Stevanović et al., 2003). Identified taxa *Polygonum albanicum*, *Gypsophila spergulifolia*, *Fumana bonapartei*, *Halacsya sendtneri*, and *S. canina* subsp. *tristis* are transregional serpentine Balkan endemics, distributed in the wider serpentine areas in the Balkans. The genus *Halacsya*, with the only species *H. sendtneri*, is a monotypic endemic-relict genus found in the investigated area. It occurs in well-developed populations and is numerous on exposed ophiolite substrates.

In the group of regional serpentine endemic taxa restricted to a single floristic subregion or province, the species *Sesleria serbica* has been identified. This species is typical for Central and Eastern Bosnia and Serbia (Stevanović et al., 2003). The area of Konjuh Mountain is considered to be the northernmost distribution point of endemic serpentinophytes in the Balkans for locally distributed serpentinophytes: *Centaurea nigrescens* subsp. *smoliensis*, *Euphorbia gregersenii*, and *Cytisus austriacus* var. *maezius* (Stevanović et al., 2003). The taxon *Cytisus austriacus var. maezius* is listed as *Chamaecytisus maezeius* K. Malý in Lubarda et al. (2014) and Stevanović et al. (2003), but according to Pifkó (2015), the name *Chamaecytisus maezeius* in these papers is mistakenly used, since this combination has never been validly published. In addition to the above-mentioned local endemics, *Viola beckiana* can also be classified in the steno-endemic group according to the First Report for the Convention on Biodiversity of Bosnia and Herzegovina (Redžić et al., 2008). The locus classicus for the description of this species is on Smolin (which is included in this research), and according to the aggregated distribution data presented by Đug et al. (2013), in addition to the Konjuh area, the species is also present in Kupres, Stolovac, near Bugojno and Han Koprivnica. *V. beckiana* has well-developed populations in Konjuh, especially in the locations of Zidine, Zelenboj, Smolin and Mala Maoča. *Euphorbia gregersenii* as steno-endemic taxa for Boasnia and Herzegovina has been described for the first time on Gostović (Tajan). It inhabits humid habitats on serpentine and often comes near streams, especially in the southwestern part of Konjuh Mt.

Previous research on the biodiversity of Konjuh Mt., published in the "Report on the baseline state of the biodiversity of the Konjuh protected landscape" (Enova, 2017), indicates the presence of a total of 11 endemic and 10 subendemic taxa. The report does not note the presence of the following taxa, which were confirmed by our survey: *Athamanta turbith* (L.) Brot. subsp. *haynaldii* (Borbás et Uechtr.) Tutin, *Cerastium rectum* Friv., *Euphorbia serpentini*, *Heliosperma pusillum subsp. monachorum* (Vis. & Pančić) Niketić & Stevanović, *Myosotis suaveolens* Willd, *Polygonum albanicum* Jáv., *Pseudofumaria alba* subsp. *leiosperma* (P. Conrath) Lidén, and *Saxifraga blavii* (Engler) Beck, but it does list *Cardamine plumierii* and *Cytisus pseudoprocimnes* as sub-endemics. During our field research, *Cardamine plumierii* was observed on the serpentine substrate on Konjuh Mt., but its map of distribution indicates a wider distribution area, which does not fit into the sub-endemic term applied in this study. We did note the presence of *Cytisus procumbens* in the surveyed area, which is morphologically quite similar to the endemic *C. pseudoprocumbens*, but the presence of the endemic species *C. pseudoprocumbens* was not confirmed.

Euphorbia montenegrina (Bald.) K. Malý was also mentioned as an endemic plant in earlier studies of this region (Public Institution Protected Landscape Konjuh, 2017), but its presence was not confirmed during our research. A recently published work on the distribution of *Euphorbia* serpenini in the area of Konjuh (Maslo et al., 2022) indicates the frequent confusion of these two species in the literature. According to the above-mentioned authors, *E. serpentini* was mistakenly referred to as *E. montenegrina* in surveys of serpentine sites in Bosnia and Herzegovina and on Konjuh in many cases, despite the different ecology of *E. montenegrina*, which prefers the alpine and subalpine habitats and limestone substrate, unlike the obligate serpentinophyte *E. serpentini*.

When comparing the results, we found similarities in the presence of endemic species with the areas around the city of Banja Luka investigated by Stupar et al. (2011): *Minuartia bosniaca, Dianthus giganteus* subsp. *croaticus*, *Pseudofumaria alba* subsp. *leiosperma*, *Onosma stellulata, Iris reichenbachii* var. *bosniaca.*

Recent studies on biodiversity have mostly focused on the Protected Landscape area. Our research indicates the presence of numerous endemic species outside the boundaries of the Protected Landscape, especially in the southwest area of Mt. Konjuh on the ophiolite bedrock and limestone habitats around Olovo, Sokolina, and the Drinjača River. The process of declaring protected areas in the Federation of Bosnia and Herzegovina below the second level of protection is given to the cantonal government. Since Konjuh mountain is the border of the canton, this area is only partially protected. According to the Federation's plans for B&H, the entire area is designated as a potential Natura 2000 habitat, which would certainly be a solution for the long-term preservation of species and ecosystems in this area.

CONCLUSIONS – *Zaključak*

The flora of Konjuh Mountain includes 31 endemic and four subendemic taxa. The largest number of endemic taxa occurs on the ophiolite substratum and consists of endemic-relict forms of serpentinophytes. The chorological spectrum is characterized by the dominance of South-European and Mediterranean-Sub-Mediterranean taxa.

A total of 18 identified endemic taxa are classified as threatened. The presence of strictly protected, critically endangered endemic-relict serpentinophytes such as *Fumana bonapartei* indicates the importance of Konjuh Mountain for the preservation of this and other steno-endemic and relict taxa. Most endemic taxa also inhabit areas outside of the Protected Landscape, particularly serpentine habitats that gravitate toward the Krivaja River basin and exposed limestone habitats. The results of this study can be useful in the preparation of studies for the integrative protection of this area as a Natura 2000 site, regardless of cantonal borders.

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SAŽETAK

Područje planine Konjuh je floristički interesantno zbog specifičnog ofiolitskog ili ultramafitnog supstrata kojeg nastanjuju serpentinofite. Već su prva detaljnija floristička istraživanja ovog područja, koja je objavila Ritter-Studnička (1955; 1963; 1970) ukazala na posebnosti ovog područja. Flora i vegetacija na peridotitima i serpentinitima planine Konjuh ima tercijarno-reliktni karakter, koji se do danas očuvao na ovim staništima tipa refugijuma, posebno u ekosistemima šuma crnog i bijelog bora, serpentinskih kamenjara i pukotina stijena. Tokom istraživanja endemske vaskularne flore, koje je vršeno u periodu od deset godina (2002–2022), obuhvaćen je širi prostor planine Konjuh, sa fokusom na serpentinska i krečnjačka staništa. Ustanovljeno je da endemsku floru planine Konjuh čini 31 takson, što je 10% od ukupnog broja biljnih endema specifičnih za područje Bosne i Hercegovine (Tabela 1). Endemska vaskularna flora planine Konjuh je svrstana u 19 familija od kojih su najbrojnije Caryophyllaceae (Grafikon 1). Najveći broj vrsta pripada serpentinofitama. Lokacije vrsta su kartografski prikazane (Slika 2). U rezultatima su navedene lokacije od posebnog interesa za dalje istraživanje i potencijalnu zaštitu zbog diverziteta endemskih taksona. Najzastupljeniji su dinarski i dinarsko-balkanski elementi iz južno-evropsko planinske horološke grupe (SEM) (Grafikon 2), što je posljedica činjenice da planinu Konjuh najvećim dijelom grade ofioliti, i da su serpentinska staništa oskudna vodom, što osigurava uslove za rast termofilnih biljnih vrsta. U endemskoj vaskularnoj glori Konjuha dominiraju hemikriptofite (Grafikon 3). Analiza kategorija ugroženosti endemičnih biljnih vrsta ukazuje da je 18 taksona svrstano u neku od kategorija ugroženosti prema Crvenoj listi flore Federacije BiH, od čega je četiri sa oznakom EN i NT, po tri u kategorijama LC, DD, i po dva sa oznakom CR i VU (Grafikon 4). Najveći broj endemskih vrsta planine Konjuh naseljava ofiolitski supstrat, odnosno vezan je za osunčana kamenjarska staništa serpentinita i peridotita, ili reliktno-refugijalne šume crnog i bijelog bora, koji predstavljaju značajnu prirodnu i konzervacijsku vrijednost ovog područja (Slike 3, 4, 5). Kritično ugrožena endemo-reliktna serpentinofita *Fumana bonapartei* raste u manjim populacijama, što ukazuje na potrebu dugoročnog očuvanja ovog područja. Areal endemičnih biljaka obuhvata širi prostor od onog koji je pod zaštitom i posebno se vezuje za serpentinska staništa koja gravitiraju prema slivu rijeke Krivaje i krečnjačka izložena staništa. Rezultati ovog rada mogu biti primjenjivi u izradi studija za integrativnu zaštitu ovog područja u vidu NATURA 2000 područja.

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ORIGINAL SCIENTIFIC PAPER

Comparative characteristics of compressed natural gas CNG and wood biomass supply chains

Uporedne karakteristike lanaca snabdijevanja komprimovanim prirodnim gasom i drvnim gorivima

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ABSTRACT

In this paper, general characteristics related to the supply chain of compressed natural gas (eng. CNG - Compressed Natural Gas) are given. Compressed natural gas is stored in a compressed gas state in tanks (bottles), in contrast to liquefied natural gas (eng. LNG - Liquefied Natural Gas) in which natural gas is stored in liquid form. The production and storage of compressed natural gas is somewhat cheaper compared to liquid natural gas, with the fact that the storage volumes are different. From all of this, there is a need to analyze the supply chain with CNG from the aspect of the compression process, transportation and storage costs. This paper describes the process of exploitation of CNG as a fuel for the conditions of functioning of the supply chain in Bosnia and Herzegovina. Real data related to the process of compression, transportation and storage of natural gas were taken from the company: "Prvo gasno društvo" D.O.O. Zvornik. The paper analyzed the indicators of the chain like energy efficiency, CO2 emissions and production cost reduced per 1 kWh of energy expressed in the lower heat value (LHV) of the distributed fuel. Also, a short comparison of the supply chains by CNG, wood pellets and chips as fuels is presented by the MCDM method. From the aspect of transport logistics, CNG has significantly better predispositions compared to other supply chains of pellets and wood chips, taking into account the energy efficiency of its process as well as the cost of supply logistics itself. However, CNG belongs to the category of fossil fuels.

Key words: *CNG, indicators, wood chips, pellets, comparison*

INTRODUCTION – *Uvod*

Zbog potreba industrijskih i komercijalnih potrošača za prirodnim gasom, a gdje ne postoji mogućnost priključivanja na gasovodnu mrežu, koristi se uskladišteni prirodni gas. Prirodni gas se može skladištiti kao tečan (*TPG – Tečni Prirodni Gas, eng. LNG - Liquefied Natural Gas*) ili kao komprimovan (*KPG – Komprimovani Prirodni Gas, eng. CNG - Compressed Natural Gas*). Razlika je u tome što se u KPG rezervoarima prirodni gas skladišti u gasovitom stanju na pritisku od 200 do 250 bara, što predstavlja gustinu od oko 130 puta veću od gustine metana na atmosferskom pritisku, za razliku od TPG rezervoara u kojima se prirodni gas skladišti u tečnoj fazi.

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Gustina metana u tečnom stanju je 610 puta veća od gustine metana pri normalnim uslovima pritiska i temperature. Proizvodnja i skladištenje komprimovanog prirodnog gasa je jeftinija u poređenju sa tečnim jer ne zahtijeva rashladne procese i kriogene temperature u rezervoarima, s tim što je za istu veličinu KPG i TPG rezervoara, masa komprimovanog gasa nešto manja.

Komprimovani prirodni gas se čuva pod visokim pritiskom (obično od 200 do 250 bara). Kako bi se uvećala količina skladištenog gasa unutar date zapremine, gas se sabija na izuzetno visoke pritiske i skladišti u specijalne boce. Sabijanje se vrši pomoću klipnih kompresora visokog pritiska i prirodni gas ostaje u gasovitom stanju tokom cijelog procesa sabijanja. Njegova priprema, odnosno čišćenje i komprimovanje, se odvija u okviru stanice za punjenje (punionice), gdje se i skladišti u posebne boce iz kojih se dalje vrši njegova distribucija (Ivošev, 2017; Semin and Abu, 2008; Todorović et al., 2017).

Proizvodnja komprimovanog prirodnog gasa

Proizvodnja komprimovanog prirodnog gasa predstavlja sabijanje prirodnog gasa iz transportnog ili distributivnog sistema prirodnog gasa, specijalnim kompresorima velikih snaga i radnog pritiska između 200 i 250 bara, na koje se sabija prirodni gas. Ovog trenutka značajniju proizvodnju komprimovanog prirodnog gasa u Bosni i Hercegovini radi preduzeće "Prvo gasno društvo" Zvornik i "Rafinerija nafte Brod a.d." Brod. Na slici 1. prikazan je izgled kompresorskog postrojenja u preduzeću "Prvo gasno društvo" Zvornik.

Figure 1. The compressor plant in the company "Prvo gasno društvo" Zvornik

Slika 1. Izgled kompresorskog postrojenja u preduzeću "Prvo gasno društvo" Zvornik

Ovo preduzeće je osnovano 2017. godine, i ima proizvodni kapacitet od 5 000 m^3/h. Djelatnost preduzeća je komprimovanje, prodaja i distribucija prirodnog gasa (KPG) na teritoriji Bosne i Hercegovine, Srbije i Crne Gore. Postrojenje za komprimovanje prirodnog gasa, odnosno proizvodnju KPG-a, čine dvije cjeline (Ivošev, 2018):

1. kompresorsko postrojenje koje je instalirano u zatvorenom objektu, i
2. platforma sa paletama i bocama komprimovanog prirodnog gasa, koja se fizički nalazi u neposrednoj blizini kompresorske stanice.

Mega platforma (interni naziv za konstrukciju platforme) u koju se privremeno ubacuje komprimovani prirodni gas, nalazi se na otvorenom prostoru, u neposrednoj blizini kompresorskih postrojenja. Konstrukcija mega platforme čini jedno stabilno, slobodno postolje, na kome se nalaze palete koje mogu biti sa različitim brojem i kapacitetima boca za KPG. Napunjena mega platforma se relativno lako i brzo postavlja na odgovarajuće specijalno prevozno sredstvo(Slika 2).

Figure 2. The mega platform of the company "Prvo gasno društvo" Zvornik

Slika 2. Izgled mega platforme preduzeća "Prvo gasno društvo" Zvornik

Armatura komprimovanog prirodnog gasa (cijevi i ventili) koja povezuje boce visokog pritiska 200–250 bara, je prilagođena ispitnim i radnim pritiscima prirodnog gasa. U decembru 2021. godine, u "Rafineriji nafte Brod a.d." Brod, puštena je u rad gasna kompresorska stanica. Rad gasne kompresorske stanice omogućen je dovodom prirodnog gasa gasovodom kojim je rafinerija spojena sa gasnim sistemom Hrvatske. Dužina gasovoda je 5,5 km, a kapacitet gasne kompresorske stanice je 40 m^3 komprimovanog prirodnog gasa, koji se dostavlja u bocama. Na slici 3. prikazan je izgled kompresorske gasne stanice u "Rafineriji nafte Brod a.d." Brod. Slike 1, 2 i 3 su lično napravili autori ovog teksta u pomenutim preduzećima.

Figure 3. The compressor gas station in "Oil Refinery Brod a.d." Brod

Slika 3. Izgled kompresorske gasne stanice u "Rafineriji nafte Brod a.d." Brod

Osnovne karakteristike transporta prirodnog gasa u komprimovanom stanju

Koncept transporta prirodnog gasa primjenom tehnologije komprimovanja (KPG), zasniva se na principu smanjenja njegove zapremine u prostoru posude, postupkom komprimovanja (sabijanja) u gasovitom stanju. Tehnologija se bazira na postupku da se, pri određenoj temperaturi i pritisku, prirodni gas u gasovitom stanju komprimuje (sabija) na viši pritisak. Na taj način se postiže da se u istu zapreminu smjesti veća količina gasa. Tehničko-tehnološka rješenja ove tehnologije relativno su jednostavna. Ona se može lako primjenjivati u komercijalne svrhe. Osnovne karakteristike ove tehnologije transporta gasa jesu: da je ona lako izvodljiva za praktičnu primjenu, jednostavna u procesu korišćenja i ekonomski prihvatljiva. Ona je mnogo prikladnija za praktičnu primjenu od TNG tehnologije. Pored osnovne tehnološke aktivnosti komprimovanja gasa, u procesu može da se primjeni i tehničko rješenje hlađenja gasa na niže temperature da bi se komprimovale veće količine gasa u isti prostor. To praktično znači da se ova tehnologija može realizovati na dva načina:

1. samo komprimovanjem zemnog (prirodnog) gasa,
2. smanjenjem njegove temperature i komprimovanjem.

Zapremina gasa, primjenom ove tehnologije, smanjuje se do 300 puta u odnosu na njegovu zapreminu u normalnim uslovima. U zavisnosti od temperature okoline i od pritiska, gas se najčešće transportuje na pritisku koji se kreće u rasponu između 82,7 i 241,3 bara. Visina temperature zavisi od metode koja se konkretno koristi za transport, ali i od tehničkih karakteristika prostora za skladištenje i kreće se u granicama od –40 °C do 45 °C. Komprimovani gas se može transportovati: brodovima, kamionima i vozovima. Njihova sama konstrukcija može biti različitog tehničkog rješenja. Cjelokupna linija snabdijevanja gasa, tehnologijom komprimovanja, od proizvodnje gasa na kopnu do potrošača, realizuje se kroz faze: same proizvodnje gasa, pripreme gasa za prevoz (dehidracija, mjerenje, komprimovanje), dopreme do utovarnog mjesta, transporta gasa (brodovima, kamionima ili vozovima), prenosa gasa do procesnog postrojenja (i/ili skladišta), njegove pripreme za tržište i distribucije (Ramoo and Parthasarathy, 2011).

Autocisterne za prevoz KPG-a

Snabdijevanje i distribucija KPG-a do potrošača izvodi se putem trajlera ili baterija sa bocama, u koje se prirodni gas puni prečišćen i komprimovan u punionicama. Za prevoz komprimovanog prirodnog gasa koriste se dva tipa autocisterni. Prvi tip su kamioni sa prikolicom na čijoj se platformi prevoze baterije sa bocama. Ova vozila su kompaktnog tipa, odnosno baterije se mogu skinuti sa platforme, što se čini kada se boce pune i u trenutku kada su priključene na regulacionu stanicu. Trajleri su autocisterne tipa kamiona sa prikolicom, koja je opremljena konvencionalnim čeličnim bocama, koje su u kavezima fiksno vezane za platformu. Ovaj tip autocisterni se može priključiti i na redukcionu stanicu za potrebe nekog gorionika. Projektovanje i izrada ovih vozila se vrši prema standardu DIN EN ISO 11120/ADR/GGVS, a radni pritisak je 250 bara. Boce mogu biti postavljeni vertikalno ili horizontalno na platformama (prikolicama) autocisterne. Prevoz komprimovanog prirodnog gasa mora da zadovoljava dva osnovna principa:

1. blagovremena doprema KPG-a korisnicima, i
2. bezbjednost u saobraćaju.

Na slici 4. prikazan je izgled klasičnog kamiona za prevoz komprimovanog prirodnog gasa.

Figure 4. Classic truck for transporting compressed natural gas (Ivošev, 2018)

Slika 4. Klasični kamion za prevoz komprimovanog prirodnog gasa (Ivošev, 2018)

Način transporta komprimovanog prirodnog gasa mora biti usaglašen sa Evropskim sporazumom o međunarodnom transportu opasnih materija (skraćenica ADR – Evropski sporazum o međunarodnom drumskom prevozu opasnih materija). Prema ovim odredbama koje se odnose na opasne materije i predmete reguliše se prevoz robe koja je deklarisana kao opasna materija (Todorović et al., 2017).

Boce za skladištenje komprimovanog prirodnog gasa

Na tržištu postoje četiri tipa posuda pod pritiskom u kojima se komprimovani prirodni gas skladišti i transportuje. Sva četiri tipa su cilindričnog oblika sa polusferničnim dancima na oba kraja. Ovakav strukturni oblik predstavlja najpovoljnije rješenje jer obezbeđuje ravnomjernu raspodjelu napona unutar cijele posude. Ključna razlika za svaki tip posude je u materijalu koji se koristi za njihovu izradu i u načinu njihove izrade. Ove karakteristike u suštini određuju ukupnu težinu i cijenu posuda, koje su i primarne pri njihovom odabiru.

Tehnički zahtjevi za KPG boce, zahtjevaju seriju povezanih sigurnosnih kriterijuma koji se odnose na kritični pritisak, vijek trajanja boce, otpornost na oštećenja i uticaj ekstremnih uslova. Standard za sve tipove boca podrazumijeva radni pritisak od 200 do 250 bar, mjeren pri tehničkim uslovima od 15 °C. Predviđeno je da rade efikasno na temperaturama od -40 do 65 °C, sa dozvoljenim mogućim rastom i do 82 °C. Kritični pritisak je uglavnom vezan za tip boce i minimalni faktor bezbjednosti od eksplozije varira u zavisnosti od standarda. Boce moraju izdržati predviđen radni vijek, koji u godini podrazumijeva najviše 1000 ciklusa godišnje punjenja u periodu od 20 godina (ISO 11439).

MATERIALS AND METHODS – *Materijal i metode*

U prethodnom izlaganju date su opšte karaktreristike KPG kao energenta. Posebnu problematiku korištenja KPG ima njegova distribucija, transport do krajnjih korisnika i korištenje. Obzirom da organizovanje lanca snabdijevanja sa komprimovanim prirodnim gasom iziskuje određene količine potrošnje i isporuke gasa za koje se moraju imaju ekonomska opravdanja za preduzeće koje se bavi isporukom ovog energenta. U tabeli 1. dati su podaci koji se odnose na proizvodnju i transport komprimovanog prirodnog gasa ustupljeni od preduzeća "Prvo gasno društvo" Zvornik. Vrijednosti u tabeli 1. preuzete su iz pomenutog preduzeća i dobijene iz prosječne godišnje statistike i bilansa koji se evidentiraju po pojedinim procesima posmatrano.

Table 1. Data on production and delivery of CNG to final consumers for "Prvo gasno društvo" Zvornik

Tabela 1. Podaci o proizvodnji i isporuci KPG krajnjim potrošačima za "Prvo gasno društvo" Zvornik

k	Utrošak energije za komprimovanje, podaci o procesu	0,076 kWh/m^3
r	Utošak ljudskog rada u postrojenju za komprimovanje	0,00409 EUR/m^3
FC	Potrošnja goriva kamiona za transport, gasni motor	60 m^3/100 km
v	Cijena rada vozača kamiona u bruto iznosu	0,00512 EUR/m^3
Tl	Uticaj vremena ležanja trajlera u ciklusu pražnjenja rezervoara na ukupnu cijenu	Ležanje trejlera duže od jednog dana se izbjegava.
cu	Cijena gasa pri ulazu u proces komprimiranja svedena po mjerenoj jedinici goriva	450 EUR/1000 m^3
ck	Cijena gasa na mjestu isporuke krajnjem korisniku svedena na jedinicu goriva	Zavisno od udaljenosti i brzine praženjenja, kreće se u intervalu od 600 do 750 EUR/1000 m^3.
NAPOMENA		Gdje se m^3 odnosi se na standardni metar kubni, 1,01 bar i 15 ^{0}C. Cijena industrijske struje je 0,14 EUR/kWh. Prosječna efikasnost proizvodnje elektične energije uzeta je 0,3.

U skladu sa prethodnom tabelom može se uspostaviti formulacijska zavisnost formiranja konačene cijene isporučenog CNG u kWh krajenjem korisniku i dati odgovore na logističke izazove transporta ovog energenta. Nakon urađenih kalkulacija koje se odnose na lanac snabdijevanja KPG (CNG-om), dobija se sljedeća tabela 2. indikatora ovog lanca (K_1, K_2, K_3). Neke od korištenih formulacija za proračun date su u nastavku redosledno. Oznake korištene u formulama od (1) do (4) kao i njihove proračunske vrijednosti nalaze se u tabeli 3. Obzirom da postoji veliki broj formulacija, daju se samo osnovne za proračun indikatora (kriterijuma K_1 do K_3).

$$E_k = \frac{\left(\frac{Vl}{z} \cdot k \cdot \rho \cdot Hdo\right)}{1000 \cdot 3{,}6} \quad (1)$$

$$K_1 = 1 - (Eko + Et) \quad (2)$$

$$K_2 = \frac{Ck \cdot pdv \cdot prof}{E_k} \quad (3)$$

$$K_3 = \frac{(Eko \cdot gu + Et \cdot gp) \cdot 3{,}6}{1000} + \frac{gp \cdot 3{,}6}{1000} \quad (4)$$

Table 2. Supply chain indicators for CNG (energy efficiency, specific production cost, specific CO2 emission)

Tabela 2. Indikatori lanca snadbijevanja sa KPG (energetska efikasnost, specifični proizvodni trošak, specifična emisija ugljen dioksida)

Kriterijumi za izbor optimalne varijante lanca snabdijevanja gorivom		
	Alterntiva 1: proizvodnja i transport CNG.	
Energetska efikasnost (K1)	0,9684	
Specifični proizvodni trošak (K2)	0,05370 EUR/ kWh	0,61303 EUR/ m^3
Specifična emisija ugljen dioksida kg/ kWh (K3)	0,23692	
NAPOMENA	Standardni metar kubni odnosi se na parametre vezane za temperaturu od 15 ^{0}C i atmosferski pritisak od 1,01 bar. Gustina gasa na standardnom kubnom metru je ρ = 0,732 kg/m^3. Zapremina boca za transport V = 40 000 m^3. Koeficijent stišljivosti prilikom komprimiranja gasa z = 0.87 (Strelec i drugi, 2014). Faktor komprimiranja gasa od 220 d0 250 bara. Kod formiranja cijena uzet je u obzir: stopa PDV-a od 17% i profit od 10%.	

Svi parametri koji su bili ulazi u proračun indikatora energetske efikasnosti K_1, specifičnog proizvodnog troška K_2 i specifične emisije ugljen dioksida dati su u tabeli 3.

Na sličan način u tabeli 4. date su karakteristike drvnog peleta i drvne sječke kao goriva za uslove koji odgovaraju Bosni i Hercegovini. Kalkulacije karakteristika lanaca u tabeli 4. urađene su uz pomoć DEP platforme za optimizaciju bioenergetskih lanaca, https://eureka.dignet.hr/ .

Na račun kalkulacija koje se odnose na lance snabdijevanja CNG-om – alternativa 1, drvnim peletom – alternativa 2 i drvnom sječkom – alternativa 3, izvršiće se upoređivanje ovih lanaca snabdijevanja. Svakako svaki lanac snabdijevanja ima smisla i opravdanosti primjenjivati na različitom lokalitetu na kojem postoje dovoljne količine posmatranog energenta i ekonomski opravdani radijusi transporta snabdijevanja. Metodologija izbora najbolje rangirane alternative uradiće se uz pomoć metode VIKOR, a za određivanje težina kriterijuma koristi se Entropy metoda. U tabeli 5. nalaze se grupisani kriterijumi od tri snabdijevačka lanca koji predstavljaju polaznu optimizacionu matricu za proračun tešina usvojenih kritreijuma i rangiranje posmatranih snabdijevačkih lanaca meotdom VIKOR. Prema metodi entropije, težine kriterijuma iznose redosledno w1 = 0,024 za K1, w2 = 0,108 za K2 i w3 = 0,868 za K3. To praktično znači da entropijska metoda daje prednost emisiji ugljen dioksida i specifičnom proizvodnom trošku u odnosu na energetsku efikasnost lanca proizvodnje. Takođe u radu je uzet u obzir i slučaj jednakosti težina kriterijuma w1 = 0,333 za K1, w2 = 0,333 za K2 i w3 = 0,333.

RESULTS AND DISCUSSION - *Rezultati i diskusija*

Rezultati i zaključci dobijeni u okviru ovog rada imaju višestruki značaj za lance snabdijevanja različitim energentima na području Bosne i Hercegovine. Što se tiče komparacije lanaca snabdijevanja uz primjenu metode VIKOR i Entropijske metode za određivanje kriterijuma, tu stvari stoje na sljedeći način. Veoma je bitno naglasiti da entropijska metoda spada u grupu objektivnih metoda za određivanje težina kriterijuma. Prema takvoj postavci prvorangirani lanac je lanac proizvodnje drvne sječke sa mobilnim iveračem u šumi, zatim slijedi proizvodnja peleta i na kraju lanac sa CNG. Rezultati su očigledni, jer je ovakav pristup posmatranja dodijelio fosilnu ulogu CNG-u u odnosu na druga dva lanca i uračunao pretpostavljenu emisiju ugljen dioksida koja bi se desila sa sagorijevanjem ovog goriva. Ostala dva lanca u smislu sagorijevanja imaju pretpostavku emisije ugljen dioksida jednaku nuli. Uzimajući u obzir drugi slučaj kada se težinama kriterijuma dodijeli jednaka vrijednost i značaj u procesu rangiranja sa metodom VIKOR, stvari se malo mijenjaju i u tom slučaju kao drugorangirana varijanta postaje lanac snabdijevanja sa CNG. Potrebno je naglasiti da posmatrajući tablicu 5. lanac snabdijevanja sa CNG je bolji po oba parametra u smislu energetske efikasnosti K1 i u smislu specifičnog proizvodnog troška K2. Međutim, mora se imati i na umu da je transport peleta u smislu ekonomski isplativog radijusa, ali i drvne sječke, pogotovo ograničen u odnosu na lanac CNG. U tom smislu daje se i prijedlog izračunavanja i ekonomskog radijusa transporta CNG u odnosu na konkurentnu cijenu peleta ili nekog drugog energenta sljedećom formulom.

Table 3. Defined parameters for the criteria calculations for the CNG supply chain

Tabela 3. Definisani parametri za proračune kriterijuma za KPG lanac snabdijevanja

ρ	0,732	kg/m³	gustina gasa na 15 ⁰C
Vl	40000	litara	zapremina trejlera
Hdo	48,837	MJ/kg	donja toplotna moć plina
k	250	bar	faktor komprimovanja
z	0,87		faktor stišljivosti
FC	60	m³/100 km	utrošak gasnog kamiona na 100 km
Cu	0,45	EUR/m³	cijena gasa na ulazu u proces
Cp	0,6	EUR/m³	tržišna cijena gasa
l	100	KM	dužina transporta
ce	0,14	EUR/kWh	cijena električne energije
k	0,076	kWh/m3	utrošak električne energije za komprimovanje
r	0,00409	EUR/m³	utrošak ljudskog rada u postrojenju za komprimovanje
v	0,00512	EUR/m³	trošak vozača kamiona
eta	0,3		efikasnost proizvodnje električne energije
gp	63	kg CO2/GJ	koeficijent emisije ugljen dioksida za prirodni gas
gu	100	kg CO2/GJ	koeficijent emisije ugljen dioksida za kameni ugalj
Vm	10000	m³	zapremina gasa koji stane u jedan trejler
M	8413,793103	kg	masa gasa jednog trejlera
Ek	114140,1149	kWh	energija sadržana u jednom trejleru
Ekm	11,41401149	kWh/m³	energija sadržana u m3
K	106,4	EUR	cijena utrošene energije komprimovanja po trejleru
R	40,9	EUR	cijena rada ljudi u postrojenju po trejleru
V	51,2	EUR	cijena troška vozača po trejleru
CU	4500	EUR	cijena gasa koji se skladišti u trejleru neposredno prije procesa komprimovanja
Tr	64,8	EUR	cijena transporta
Ck	4763,3	EUR	ukupni trošak po trejleru
pdv	1,17	17%	porez na dodatnu vrijednost
prof	1,1	10%	profit
Ckm3	0,61303671	EUR/m³	konačna cijena gasa na isporuci korisniku izražena u EUR/m³
K2	0,053709137	EUR/kWh	konačna cijena gasa na isporuci korisniku izražena u EUR/kWh
Eko	0,022194943	kWh/kWh	utrošena energija po 1 kWh komprimovanog gasa
Et	0,009396	kWh/kWh	utrošena energija po 1 kWh transportovanog gasa
K1	0,968409057		energetska efikasnost procesa komprimiranja i transporta CNG-a
K3	0,236921192	kg/kWh	emisija ugljen dioksida, uzeto u obzir energija komprimovanja i potrošnja gasa prilikom tansporta

Table 4. Supply chain indicators for wood pellets and chips (energy efficiency, specific production cost, specific CO2 emission)

Tabela 4. Indikatori lanca snadbijevanja sa drvnim peletom i sječkom (energetska efikasnost, specifični proizvodni trošak, specifična emisija ugljen dioksida)

Kriterijumi za izbor optimalne varijante lanca snabdijevanja gorivom				
	Alternativa 2: proizvodnja peleta		**Alterntiva 3:** proizvodnja sječke mobilnim iveračem u šumi	
Energetska efikasnost (K1)	0,6953		0,9701	
Specifični proizvodni trošak (K2)	0,06935 EUR/kWh	312 EUR/ton	0,03075 EUR/ kWh	73 EUR/ton
Specifična emisija ugljen dioksida kg/kWh (K3)	0,0924		0,0082	
Značajni parametri:	cijena benzina 1,3 EUR/l, cijena nafte 1,3 EUR/l, cijena struje 0,148 EUR/kWh, dužina tranporta drvnog ostatka 60 km, dužina transporta drvog peleta 100 km, prosječna dnevnica ljudskog rada 40 km po danu, početna količina vlage u drvnom ostatku w = 50%, cijena drvnog ostatka 30 EUR/toni.		cijena benzina 1,3 EUR/l, cijena nafte 1,3 EUR/l, dužina privlačenja skiderom do 1 km, dužina transporta drvne sječke 100 km, prosječna dnevnica ljudskog rada 40 km po danu, početna količina vlage u drvnom ostatku w = 50%, cijena šumskog ostatka 25 EUR/toni.	
NAPOMENA	U lance proizvodnje peleta i drvne sječke uključeni su svi oni elementi koji doprinose njihovom funkcionisanju. Lanac proizvodnje peleta primarno koristi drvni ostatak od prerade sa pilana, dok lanac proizvodnje drvne sječke odnosi se preradu ostatka od sječe u šumi. Lanac peleta uključuje elemente poput: kamiona za transport drvnog ostaka, pelet postrojenja, viljuškara i kamiona za transport peleta. Lanac proizvodnje drvne sječke uključuje: motornu pilu, skider, mobilni iverač, kamion za transport drvnog čipsa. Kod formiranja cijena uzet je u obzir: stopa PDV-a od 17% i profit od 10%.			

Uzimajući u obzir prethodnu formulaciju kao i navedenu cijenu peleta od 612 EUR/ton u posmatranom modelu, pretpostavljenu toplotnu moć tone peleta od 4500 kWh, prema toj postavci uz zadržavanje svih parametara posmatranog CNG procesa, dozvoljeni radijus transporta komprimovanog gasa se kreće čak i do 2200 km. Međutim, obzirom da su tržišne cijene jako varijabilne i uzimajući u obzir tu činjenicu da je trenutna cijena peleta oko 250 EUR/tona, što je ekvivalent od oko 0.05555 EUR/kWh, u tom slučaju distanca transporta CNG za cijenu od 0.05370 EUR/kWh, iznosi samo 350 km. Ovo sve ukazuje na to da ukoliko se cijena peleta smanji za nešto više od 50 EUR/toni, radijus transporta CNG se smanjuje za oko 6 puta, za pretpostavljenu konkurentnost naspram cijeni peleta u odnosu na postavke modela. Na osnovu obrnutog posmatranja problematike logistike CNG ali i trenutnog stanja cijena energenata na tržištu, može se doći do vrlo upotrebljivih podataka za organizaciju procesa distribucije CNG.

Na osnovu evropske direktive "Directive 2009/28/EC of the European Parliament and of the Council on the promotion of the use of energy from renewable sources" koja svrstava toplotne pumpe u obnovljive izvore energije, u zavisnosti od minimalne vrijednosti sezonskog faktora grijanja (performanse), (SCOP, Seasonal Coefficient of Performance). Prema anakesu VII Direktive 2009/28/EC obnovljivim izvorom se smatraju samo toplotne pumpe koje ispunjavaju uslov:

$$SCOPO > 1{,}15 * 1/\eta. \qquad (6)$$

Zamišljena energetska efikasnost sistema za proizvodnju toplote postavljena je na vrijednost η = 0,455 (ili 45,5%) bazirano na podatke za 2010. godinu, i to je vrijednost koja je trebala da se koristi do 2020. godine (za EU). Ukoliko se postavi η = 0,455 dobija se da vrijednost prosječnog sezonskog grejnog faktora SCOP toplotne pumpe pokretane električnom energijom proizvedenom iz fosilnih goriva mora iznositi minimum 2,5 da bi se ona smatrala obnovljivim izvorom energije. Dakle, uslov je da je SCOP > 2,5 toplotne pumpe pokretane električnom energijom sa fosilnim otiskom prema standardu EN 14825:2012, koji mora biti zadovoljen. S tim u vezi uzimajući efikasnost kotla na gas od 95%, SCOP toplotne pumpe trebao bi imati ekvivalent jednak preko 3,3 da bi ostvario smanjenje emisije ugljen dioksida u odnosu na gasni kotao. U cijelo razmatranje

Table 5. Supply chain indicators of fules

Tabela 5. Indikatori lanca snadbijevanja gorivima

Kriterijumi za izbor optimalne varijante lanca snabdijevanja gorivom			
	Alterntiva 1: proizvodnja i transport CNG	**Alternativa 2:** proizvodnja peleta	**Alterntiva 3:** proizvodnja sječke mobilnim iveračem u šumi
Energetska efikasnost (K1)	0,9684	0,6953	0,9701
Specifični proizvodni trošak (K2) EUR/ kWh	0,05370	0,06935	0,03075
Specifična emisija ugljen dioksida kg/kWh (K3)	0,23692	0,0924	0,0082

ulazi se sa pretpostvkom da je toplotna pumpa pogonjena električnom energijom dobijenom iz fosilnih goriva. U slučajevima smanjene efiskanosti proizvodnje električne energije, vrijednosti SCOP-a trebale bi biti i preko 4 da bi toplotna pumpa prešla u režim rada sa manjom emisijom u odnosu na gasni kotao. Postoje različite analize koje vrše komparaciju ovih tehničkih sistema sa stanovišta emisije ugljen dioksida (Lin et al., 2021).

Bitno je napomenuti pored svih prednosti koje imaju aspekti primjene CNG-a, da to gorivo ipak predstavlja fosilno gorivo.

CONCLUSIONS – *Zaključak*

Pored finansijskih opravdanosti korištenja CNG-a, značajni aspekti njegovog korištenja ogledaju se u ekološkom pogledu sagorijevanja ovog energenata, u očuvanju prirode i zdravlja ljudi i što manjem broju emisija opasnih i štetnih produkata sagorijevanja u dimnim gasovima. Upotreba komprimovanog prirodnog gasa (KPG), kao energenta za industrijske kotlove, u širem smislu, predstavlja aktivnost u oblasti poboljšanja energetske efikasnosti, zaštite životne sredine, čuvanja prirode i zdravlja ljudi. U užem smislu, cilj je eliminisanje iz upotrebe tečnih naftnih derivata (mazuta, lož ulja i sl.), kao pogonskih goriva, zamjenom za energetski efikasne i ekološki čistije energente – kao što su drvna biomasa ili komprimovani prirodni gas (KPG). Korišćenje gasa danas ima prednost u odnosu na čvrsta i tečna konvencionalna fosilna goriva, čije su zalihe već iscrpljene, a osim toga njihovim sagorijevanjem emituju se štetni gasovi i materije, što doprinosi zagađenju svih ambijenata životne sredine.

Korišćenje komprimovanog prirodnog gasa u industrijskim kotlarnicama, upotrebljava se u slučajevima kada ne postoje gasovodi prirodnog gasa, kao i u onim slučajevima gdje ne postoji praktična mogućnost priključenja na distributivnu mrežu prirodnog gasa. Upotrebom kotlarnica koje kao energent koriste prirodni komprimovani gasa (KPG), umjesto lož ulja ili mazuta, eliminišu se emisije opasnih i štetnih produkata sagorijevanja iz dimnih gasova (sumpor-dioksid, azotne okside, ugljen-monoksid i čađ). Uštede prilikom upotrebe kotlova na prirodni gas zavise od troškova, a troškovi zavise od cijene energenata u ovom slučaju prirodnog komprimovanog gasa, koji su promjenljivi.

Prema postavci izračunatih indikatora posmatranih indikatora logistike, uz upotrebu metode VIKOR kao i entropijske metode za određivanje težina kriterijuma, prvorangirani lanac je lanac proizvodnje drvne sječke sa mobilnim iveračem u šumi, zatim slijedi proizvodnja peleta i na kraju lanac sa CNG. U slučaju jednakosti težina kriterijuma i u ponovljenom procesu rangiranja sa metodom VIKOR stvari se malo mijenjaju i u tom slučaju kao drugorangirana varijanta postaje lanac snabdijevanja sa CNG. Potrebno je naglasiti da posmatrajući tablicu 5. lanac snabdijevanja sa CNG je bolji po oba parametra u smislu energetske efikasnosti K1 i u smislu specifičnog proizvodnog troška K2. Također, u radu su razvijene sve osnovne formulacije koje opisuju proces i logistiku snabdijevanja sa CNG kao gorivom, uključujući i definisanje ekonomične distance transporta komprimovanog gasa.

U Bosni i Hercegovini nije u dovoljnoj mjeri razvijena mreža za distribuciju prirodnog gasa tako da svi potencijalni potrošači nisu u mogućnosti da koriste ovaj energent. To znači da korišćenje komprimovanog prirodnog gasa na velikom dijelu teritorije Bosne i Hercegovine trenutno ima značajnu ulogu, a procjene su da će i u bližoj budućnosti tako ostati. U ovom radu su predloženi kriterijumi koji daju mogućnost međusobne komparacije sa drugim energentima, kao i svi aspekti koji utiču na isplativost ovog procesa i moguće scenarije koji nastupaju sa varijacijom cijena energenata na tržištu. S druge strane, dat je i pogled na emisije ugljen dioksida koje produkuju različiti lanci snabdijevanja bazirani na biomasi u odnosu na sam lanac snabdijevanja sa CNG. Treba uzeti u obzir da se CNG koristi za industrijske i komercijalne potrebe potrošača za prirodnim gasom, dok se za proizvodnju toplotne energije za zagrijavanje stambenih objekata ili za proizvodnju potrošne tople vode koriste uglavnom sječka i pelet koji imaju ograničene mogućnosti korištenja za određene specifične industrijske procese. U tom pogledu CNG ima jako velike mogućnosti. Također, emisija ugljen dioksida za sagorijevanje biomase uzeta je da je jednaka nuli zbog opšte prihvaćene tvrdnje o njenoj neutralnosti po pitanju ciklusa ugljenika. CNG je jako pogodno riješenje za određene tranzitne situacije koje se pojavljuju u energetici i treba značajno razmisliti o njegovim mogućnostima u tom pogledu.

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SUMMARY

In this paper, general characteristics related to the supply chain of compressed natural gas (eng. CNG - Compressed Natural Gas) are given. Compressed natural gas is stored in a compressed gas state in tanks (bottles), in contrast to liquefied natural gas (eng. LNG - Liquefied Natural Gas) in which natural gas is stored in liquid form. The production and storage of compressed natural gas is somewhat cheaper compared to liquid natural gas, with the fact that the storage volumes are different. From all of this, there is a need to analyze the supply chain with CNG from the aspect of the compression process, transportation and storage costs. This paper describes the process of exploitation of CNG as a fuel for the conditions of functioning of the supply chain in Bosnia and Herzegovina. Real data related to the process of compression, transportation and storage of natural gas were taken from the company: "Prvo gasno društvo, D.O.O. Zvornik". The paper analyzed the indicators of the chain like energy efficiency, CO_2 emissions and production cost reduced per 1 kWh of energy expressed in the lower heat value (LHV) of the distributed fuel. Also, a short comparison the supply chains by CNG, wood pellets and chips as fuels are presented by the MCDM method.

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ORIGINAL SCIENTIFIC PAPER

Antioxidant and antimicrobial potential of essential oils of different types of pepper (*Piper sp.*)

Antioksidativni i antimikrobni potencijal eteričnih ulja različitih vrsta bibera (*Piper sp.*)

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ABSTRACT

Essential oils are mixtures of potent compounds with biological effects, such as those with antioxidant, antimicrobial, antitumor and/or anti-inflammatory effects. In this paper, the antioxidant and antimicrobial activity of essential oils of different types of commercial pepper was tested. Essential oils are prepared by hydrodistillation. Polyphenol content, reduction potential and DPPH radical inhibition were analyzed. Antimicrobial activity was tested on reference strains using the diffusion technique. The analysis showed that the essential oil of black pepper has a significantly higher antioxidant potential compared to the essential oils of green and white pepper. High antimicrobial activity was also found for the black pepper essential oil sample, except in the case of *Pseudomonas aeruginosa*.

Key words: *black pepper, white pepper, green pepper, FRAP, DPPH*

INTRODUCTION - *Uvod*

Piper nigrum L. is an aromatic plant that belongs to the Piperaceae family. This plant is cultivated in tropical regions such as central and northern South America, and the Asia Pacific region. Since prehistoric times *Piper* sp. have been used by humans mainly as spices and in folk medicine to treat many diseases. Due to diverse biological activities, mainly anti-inflammatory and analgesic properties, many species of *Piper* have the potential for use in the pharmaceutical industry (Dyer et al., 2004). Essential oils are complex mixtures of volatile substances that are lipophilic. They can contain different compounds at various concentrations. The composition of essential oils is not constant and varies according to genotype, environmental factors, geographical origin, and plant cultivation and collection procedures (Bakkali et al., 2008). The pepper essential oils are characterized by the presence of monoterpenes, sesquiterpenes and phenylpropanoids with significant biological effects (Parmar et al., 1997). Essential oils from pepper are an important source of substances that have biological properties such as antioxidant, antimicrobial, anti-inflammatory and antifungal activities (Silva et al., 2020, Chahal et al., 2011). The antioxidant activity of essential oils of different types of pepper has been confirmed

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through several studies (Wang et al., 2021; Zhang and Xu, 2015). The aim of this study was to evaluate the antioxidant and antimicrobial activity of the essential oils obtained by hydrodistillation of three commercially available pepper samples.

MATERIALS AND METHODS – *Materijal i metode*

All pepper seed samples were commercially available. White pepper originates from India, while green and black pepper originate from Brazil. Demineralized water was used to prepare the solution for spectroscopic measurements. Folin-Ciocalteu reagent for testing polyphenol content and sodium carbonate were purchased from Semikem, Bosnia and Herzegovina. Methanol HPLC grade, 2,4,6-Tripyndyl-s-triazine, iron(III) chloride, hydrochloric acid, sodium acetate and 2,2-diphenyl-1-picrylhydrazyl (DPPH) were purchased from Sigma-Aldrich (USA). Spectroscopic measurements were performed on a Perkin Elmer λ25 spectrophotometer.

Hydrodistillation

Five hundred grams of finely ground pepper samples were subjected to hydrodistillation using Clevenger-type apparatus for 5 h according to the European Pharmacopoeia. Essential oils were dried over sodium sulfate anhydrous and the sample was stored at 4°C before use.

Determination of total phenolic content (TPC)

Total phenolic compounds present in the essential oil were quantified spectrophotometrically through the Folin-Ciocalteu test following the protocol (Singleton et al., 1999). 200 µL of essential oil was mixed with 2.54 mL of 10% Folin-Ciocalteu reagent. After 5 min 420 µL of 10% sodium carbonate was added. 910 µL distilled water was added to each sample prior to measuring. The absorbance of the resulting blue-coloured solution was measured at 765 nm.

Examination of the reducing ability (FRAP method)

The test of the reducing ability of the essential oil was tested using the FRAP (ferric reducing antioxidant power) method, according to the published procedure (Benzie and Strain, 1999). 3 mL of prepared FRAP reagent was mixed with 100 µL of essential oil. Absorbance was measured at 593 nm after 30 min incubation at 37°C.

Inhibition of DPPH radicals

A DPPH radical inhibition assay was performed according to a published method (Horozić et al., 2019). Essential oils were mixed with absolute methanol and then mixed with DPPH radical solution. Absorbance measurements were performed at 517 nm, after which DPPH radical inhibition was calculated according to the equation:

$$I = \frac{Ac - As}{Ac} x100$$

where As is the absorbance of the solution containing the sample at 517 nm, and Ac is the absorbance of the DPPH solution.

Analysis of antimicrobial activity

The *in vitro* antibacterial activities of the essential oils were investigated using Gram-positive bacteria (*B. subtilis* and *S. aureus*) and Gram-negative bacteria (*E. coli* and *P. aeruginosa*). *C. albicans* was used to test the antifungal activity of the isolated oils. From the microorganisms strains of overnight cultures, suspensions of 0.5 McFarland turbidity were prepared (density 10^7-10^8 CFU/mL). The strains were then placed on the surface of the nutrient substrate Mueller-Hinton agar, and dispersed in sterile Petri dishes. Substrate thickness was 4 mm. In the agar, sterile drill-shaped holes were made ("wells"), into which 100 µL of essential oil was poured. After the plates were left at room temperature for 15 minutes,

Table 2. Polyphenol content and antioxidant activity of pepper essential oils

Tabela 2. Sadržaj polifenola i antioksidativna aktivnost eteričnih ulja bibera

Samples	TPC [mg GAE/g]	FRAP [µmol/g]	IC_{50} [mg/mL]
Black pepper	1.21	86.16	7.67
Green pepper	0.40	25.6	40.86
White pepper	0.94	28.8	45.02
Vitamin C	-	14 250	0.03

the substance was diffused into agar, incubated at 37°C/24 h. After the incubation period, the size of the inhibitory zone was measured.

RESULTS - *Rezultati*

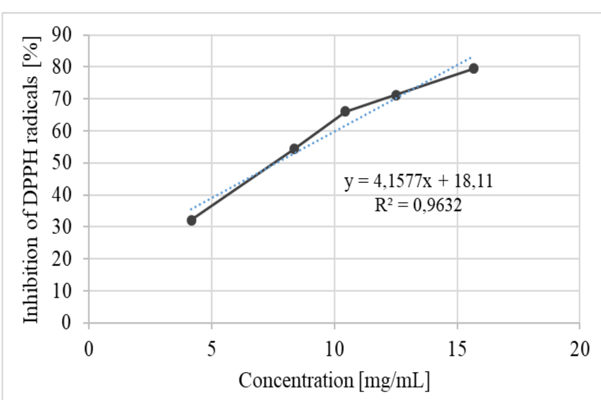
Hydrodistillation obtained essential oils with a particularly strong aroma, with a good yield. Table 1 shows the yield of isolated oil depending on the type of pepper.

Table 1. Yields of isolated pepper essential oils

Tabela 1. Prinosi izoliranih eteričnih ulja bibera

Essential oil	Yield [%]
Black pepper	1.34
Green pepper	0.47
White pepper	1.77

Table 2 shows the results of the content of polyphenols, as well as the values of reduction potential and DPPH radical inhibition in *in vitro* conditions. Vitamin C was used as a reference. Figure 1 shows graphs of the dependence of DPPH radical inhibition on concentration, through which the IC50 value for essential oil samples was calculated.



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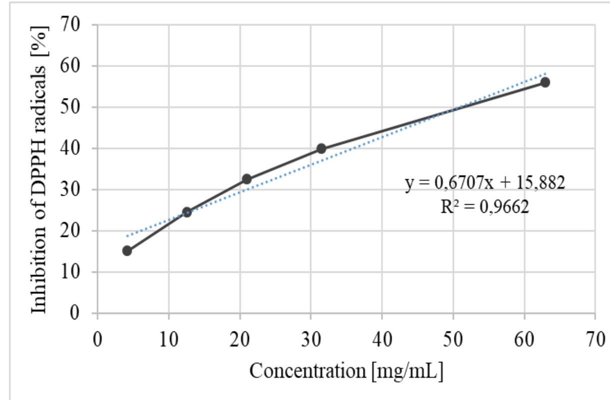

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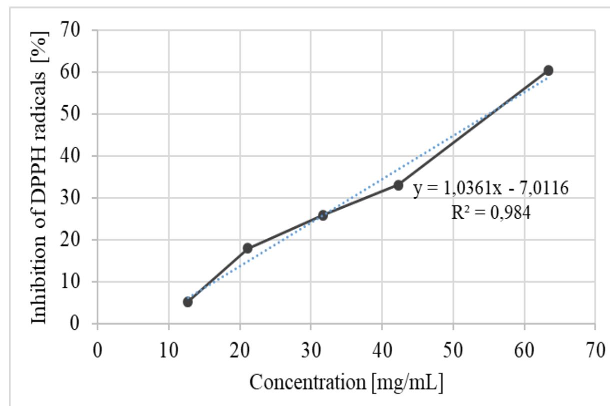

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Graph 1. Representation of the dependence of oil concentration on the percentage of quenching of DPPH radicals: (A) black pepper, (B) green pepper and (C) white pepper

Grafikon 1. Prikaz ovisnosti koncentracije ulja od procenta gašenja DPPH radikala (A) crnog bibera, (B) zelenog bibera i (C) bijelog bibera

Table 3 shows the results of testing antimicrobial activity in *in vitro* conditions.

Table 3. Antimicrobial activity of pepper essential oils

Tabela 3. Antimikrobna aktivnost eteričnih ulja bibera

Essential oil	Inhibition zone [mm]				
	E. coli	***P. aeruginosa***	***S. aureus***	***B. subtilis***	***C. albicans***
Black pepper	10	NA	15	15	13
Green pepper	9	NA	12	11	9
White pepper	NA	NA	8	NA	9

*NA - No activity

DISCUSSION – *Diskusija*

The content of polyphenols in essential oils of commercial peppers is relatively low, and is correlated with antioxidant capacity. The highest total phenol content was measured in the black pepper sample which also showed the highest antioxidant potential. Li et al. (2020) recently studied black and white pepper and they found that black pepper fruit was slightly better than white pepper fruit in terms of antioxidant activity. From Table 2 it can be seen that the effective concentration (EC50) value of the black pepper fruit was 7.67 mg/mL, which is in good agreement with the previous study (Wang et al., 2021). However, these values obtained for white pepper are significantly lower than those reported previously (Zhang and Xu, 2015). The DPPH radical neutralization efficiency as well as the reduction potential of all tested essential oils is significantly lower than the values obtained for vitamin C, well known antioxidant which was used as a control.

Pepper essential oils generally showed a better antimicrobial effect against gram-positive bacteria *B. subtilis* and *S. aureus*, with an inhibition zone in the range of 8-15 mm. The highest sensitivity was confirmed with the essential oil of black and green pepper. White pepper essential oil showed extremely weak antimicrobial activity in *in vitro* conditions. All tested samples showed antifungal activity. Through research conducted in the last few years, the antibacterial effect of the essential oil of black (Morsy and El-Salam, 2017; Hikal, 2018), white (Singh et al., 2013) and green pepper (Myszka et al., 2019) has been confirmed. In the aforementioned studies, larger zones of inhibition were recorded, which can be explained by the different origin of the samples, and the way the samples were treated and stored.

The presence of terpenoids in pepper essential oil is responsible for its antimicrobial potential (Menon et al., 2003). An important characteristic of essential oil components is their hydrophobicity, which enables them to partition into the lipids of the bacterial cell membrane, disturbing the cell structures, rendering them more permeable, and leading to lysis and leakage of intracellular compounds (Gill and Holley, 2006; Bajpai et al., 2013).

This study on the antioxidant and antimicrobial activities of essential oil from black, green and white pepper fruit proves that pepper essential oils exhibit antioxidant and antimicrobial effects owing to their active components. Black pepper essential oil was more effective than white and green pepper essential oil which is caused by differences in essential oil compositions. From the result of this study, it can be concluded that pepper essential oils have great potential as a natural source of therapeutic agent for bacterial infection. Further studies regarding the chemical composition of essential oils should be performed.

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SAŽETAK

Eterična ulja su mješavine potentnih spojeva s biološkim djelovanjem, poput onih s antioksidativnim, antimikrobnim, antitumorskim i/ili protuupalnim djelovanjem. U ovom radu ispitana je antioksidativna i antimikrobna aktivnost eteričnih ulja različitih vrsta komercijalnog bibera. Eterična ulja su pripremljena hidrodestilacijom. Analiziran je sadržaj polifenola, redukcijski potencijal ulja i inhibicija DPPH radikala. Antimikrobna aktivnost ispitana je difuzionom tehnikom na referentnim sojevima. Analiza je pokazala da eterično ulje crnog bibera ima značajno veći antioksidativni potencijal u odnosu na eterična ulja zelenog i bijelog bibera. Za uzorak eteričnog ulja crnog bibera također je utvrđena visoka antimikrobna aktivnost, osim u slučaju *Pseudomonas aeruginosa*.

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ORIGINAL SCIENTIFIC PAPER

Dendrometric characteristics of Balkan maple (*Acer heldreichii*. Orph.) in the eastern part of Bosnia and Herzegovina

Dendrometrijske karakteristike planinskog javora (*Acer heldreichii*. Orph.) u istočnom dijelu Bosne i Hercegovine

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ABSTRACT

Balkan maple spreads throughout the entire Balkan Peninsula from Greece in the south, Bulgaria, North Macedonia, Albania, Montenegro, Bosnia and Herzegovina, all the way to the northernmost deposit in Serbia on Rudnik Mountain, and the northernmost deposit in Bosnia and Herzegovina on the slopes of Trebević Mountain. This study presents the results of dendrometric characteristics of Balkan maple at the Trebević, Jahorina, and Tvičijak sites near Rogatica. The analysis included a total of 75 trees, where all the trees of the Balkan maple were found and marked by examining the three mentioned research sites. Populations of Balkan maple were found on the north and northeast exposure of the investigated areas at altitudes up to 1570 m, which also shows, according to previous research, that the largest quantity and coverage, as well as the greatest dimension of Balkan maple are reached in subalpine vegetation. Balkan maple has great significance in terms of protecting the soil from erosion, improving ecological conditions for the survival of other plant species, and due to the increasing frequency of logging for the purpose of forming ski slopes, cable cars and power lines on our mountains, Balkan maple is becoming increasingly rare, so it needs to be given much more attention.

***Key words**: Balkan maple, Acer heldreichii, Trebević, Jahorina, Rogatica, Bosnia and Herzegovina, height, diameter at Breast Height (DBH), dendrometric characteristics*

INTRODUCTION - *Uvod*

Balkansko poluostrvo je najbogatiji i najraznovrsniji dio Evropskog kontinenta u pogledu flore. Procjenjuje se da flora Balkanskog poluostrva sadrži između 7500 i 8000 autohtonih vrsta vaskularnih biljaka, što čini Balkansko poluostrvo floristički najbogatijim i najraznovrsnijim dijelom Evrope (Tutin et al. 1964-1980; Stevanović et al. 1995). Planinski javor pripada dinarsko-balkanskomezijskom flornom elementu i predstavlja endemit Balkanskog poluostrva (Tomović 2007). Raste u Srbiji, Crnoj Gori, Bosni i Hercegovini, Makedoniji, Bugarskoj, Grčkoj i Albaniji. Zapadna granica rasprostranjenja planinskog javora nalazi se na planini Bjelašnici kod Gacka u Bosni i Hercegovini, na jugu dopire do sjevernog Peloponeza u Grčkoj, na istoku do srednjeg dijela Stare planine u Bugarskoj, a sjeverna granica areala je na planini Rudnik u Srbiji (Lakušić, R. 1964).

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Krajem 19. i početkom 20. stoljeća različiti botaničari proučavali su planinski javor na području Bosne i Hercegovine, uključujući Murbecka, Malya, Fialu, Becka i Muravjeva (Fukarek 1948). Fukarek (1943, 1948) daje pregled poznatih nalazišta planinskog javora u Bosni i Hercegovini i nekim okolnim krajevima. Maly (1938, 1940) prvi navodi 12 nalazišta planinskog javora za Ravnu planinu (Jahorina), gdje ga detaljno proučava, dok Ćurić (1960) navodi nova nalazišta planinskog javora na Jahorini ispod glavnog masiva do ogranka Klek. Prema Fukareku (1965) često ga pronalazimo pojedinačno i u predplaninskim šumama bukve zajedno sa gorskim javorom. Na području Bosne i Hercegovine planinski javor je prisutan na sljedećim lokalitetima: Jahorina, Trebević, Klek kod Prače, Kmur kod Foče, Radomišlje, Treskavica, Zelengora, Volujak, Maglić i Bjelašnica kod Gacka (Perović 2013).

Planinski javor ima široku ekološku valencu u odnosu na geološku podlogu i zemljište. Izrazito je planinska vrsta i odlično podnosi niske temperature kao i dugo zadržavanje snijega i kratke vegetacione periode (Stefanović 1990). Raste na svim tipovima stijena, na krečnjačkim i silikatnim masivima, a rasprostranjen je na različitim tipovima zemljišta, od organomineralnih rendzina do kiselih smeđih zemljišta i podzola (Lakušić 1989).

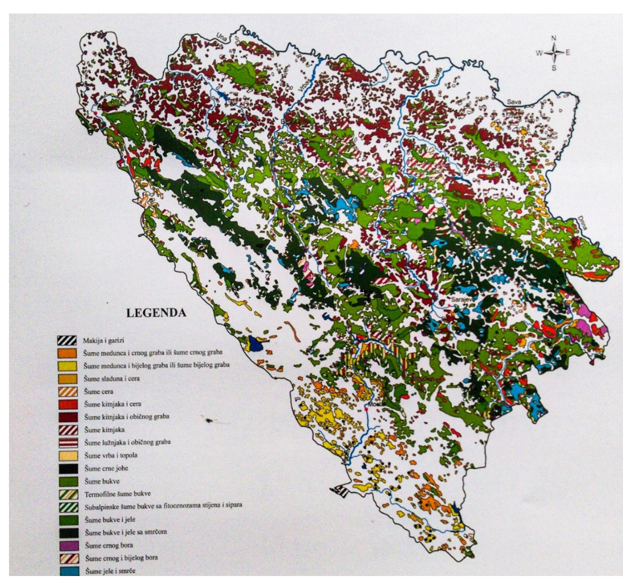
Neplanskom sječom i nestavljanjem pod zaštitu ove vrste, došlo je do istrebljenja planinskog javora te ga pronalazimo u manjim fragmentima ili pojedinačno. Ova istraživanja će imati veliki značaj ako se ima na umu da planinski javor ima sposobnost rasta u uslovima u kojima samo mali broj vrsta drveća može da opstane, zbog čega ima veliki ekološki značaj na prirodnim nalazištima. On štiti zemljišta od erozije, poboljšava ekološke uslove za opstanak drugih biljnih vrsta i predstavlja stanište i izvor hrane za znatan broj životinjskih vrsta.

RESEARCH AREA - *Područje istraživanja*

Područje istraživanja najvećim dijelom pripada kompleksu acidofilnih četinarskih šuma na plitkom krečnjačkom zemljištu. Prema horizontalnom raščlanjenju šumske vegetacije u bivšoj Jugoslaviji (Stefanović et. al 1983), ovo područje pripada oblasti unutrašnjih dinarida, području istočnobosanske visoravni.

Područje istočnobosanske visoravni obuhvata planinske krajeve oko Sarajeva i Vareša, do kanjona Drine, sa veoma izraženom Romanijskom visoravni kao i Jahorinskog platoa. U geološkoj građi ovog područja učestvuju raznovrsne sedimentne, magmatske i metamorfne stijene – paleozoika, mezozoika i kenozoika (Antić et al. 1972). Područje Trebevića, Jahorine i Tvičijaka pripada zoni mezozojskih krečnjaka. Područje ovih planina većim dijelom leži iznad 1000 m/n. v. Klima ima planinski karakter (Milosavljević 1977), mada od novembra do maja osjeća se uticaj kontinentalne klime. U vegetacionom periodu padne približno 52% godišnjih padavina, dok vegetacioni period traje u periodu od 1. 5. do 31. 9. (približno 150 dana). Prosječna srednja temperatura vazduha u vegetacionom periodu iznosi 13,8 °C, prosječna godišnja količina padavina iznosi 921,7 mm/m², pojava kasnih mrazeva događa se u junu, a ranih mrazeva u septembru (Republički hidrometeorolški zavod Republika Srpska).

Realna slika šumske vegetacije (Fotografija 1) predstavlja rezultantu djelovanja triju važnih faktora: historijskog razvoja vegetacije u prošlosti, specifičnih prirodnih uslova i antropogenih uticaja (Ćirić et al. 1971). Smrča, odnosno šumske zajednice u kojima je ova vrsta edifikator, su dominatno zastupljene kao šume bukve i jele sa smrčom (*Piceo-Fago-Abietetum* Čol. 1965) i rasprostranjene su u centralno dinarskim planinskim područjima koja su hladnija, izvan toplih klimatskih uticaja panonskog, odnosno mediteranskog područja (Stefanović et al. 1983; Beus 1984). Šume jele i smrče (*Abieti-Piceetum abietis* Mišić & Popović 1978) su rasprostranjene širom Bosne na području Kupresa, Vranice, Vlašića, Zvijezde, Romanije, Jahorine, te na području Čelebića i Meštrovca. Zauzimaju površine unutar areala klimaregionalne zajednice bukve i jele (*Abieti-Fagetum dinaricum* Treg. 1957.), dok su manje zastupljene čiste planinske šume bukve na zemljištima bogatim bazama (*Fagetum montanum* Fukarek & Stefanović 1958) i acidofilne šume bukve (*Luzulo-Fagetum* Wrab. 1969).



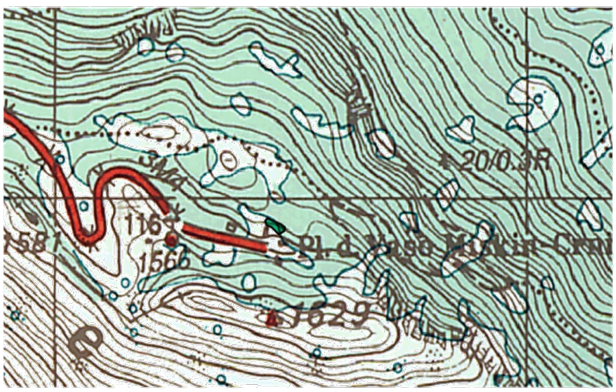
Fotografija 1. Karta realne vegetacije u Bosni i Hercegovini (Stevanović et al. 1983)

Picture 1. The map of vegetation in Bosnia and Herzegovina (Stevanović et al. 1983)

Trebević je planina u jugoistočnom dijelu Bosne i Hercegovine sa najvišom nadmorskom visinom od 1629 metara (Fotografija 2). Nalazi se jugoistočno od Sarajeva i izdiže se između klisure Miljacke na sjeveroistoku i klisure Kasindolske rijeke na jugozapadu, sarajevske kotline na sjeverozapadu, te uzvišenja Veliki i Mali Stupanj na jugoistoku, sa koordinatama 43 7969 i 18 4758. Planinski masiv planine Trebević nadovezuje se na planinu Jahorinu. Populacije planinskog javora su pronađene na sjevernoj ekspoziciji i nadmorskoj visini od 1540 m.

PLANINSKI JAVOR - TREBEVIĆ

1 : 5 000



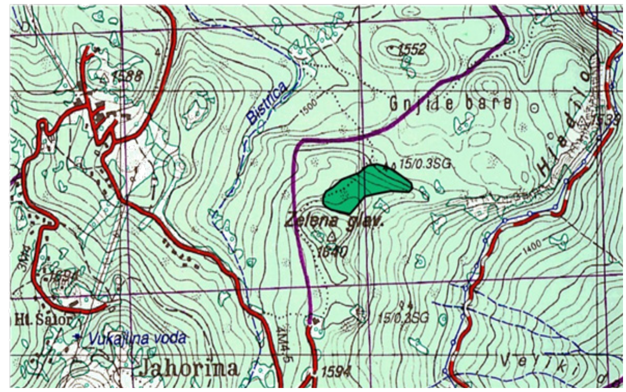
Fotografija 2. Karta nalazišta planinskog javora na planini Trebević

Picture 2. Map of Balkan maple sites on Trebević mountain

Jahorina je planina u Bosni i Hercegovini sa najvišim vrhom Ogorjelica koji se nalazi na nadmorskoj visini od 1916 metara nadmorske visine. Planina Jahorina se prostire između 43°39' 22 geografske širine i 18°31' 71 geografske dužine. Jedan od prvih istraživača vegetacije Jahorine bio je Slavnić (1954). Fukarek i Stefanović istraživali su šumsku vegetaciju 1958. godine, a Bjelčić (1966) je isto radio sa livadama i pašnjacima. Sve navedene planine pripadaju Dinarskom planinskom masivu (Fotografija 3). Populacije planinskog javora su pronađene na sjeveroistočnoj ekspoziciji i nadmorskoj visini od 1570 m.

PLANINSKI JAVOR - JAHORINA

1 : 10 000



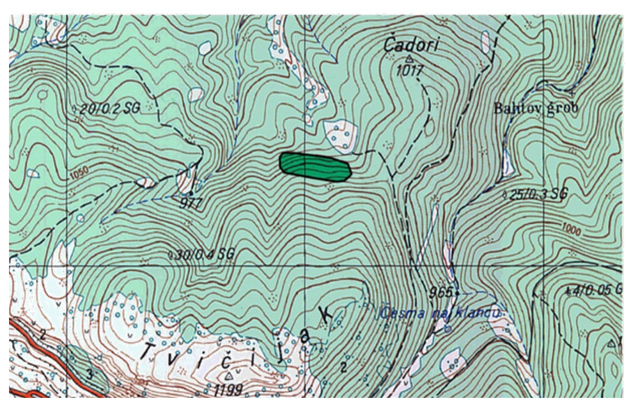
Fotografija 3. Karta nalazišta planinskog javora na lokalitetu planine Jahorine

Picture 3. Map of Balkan maple sites on the Jahorina mountain location

Kota Tvičijak nalazi se u širem okruženju grada Rogatice i najbliža je naseljenom mjestu Mesići. Nadmorska visina vrha Tvičijak iznosi 1199 metara nadmorske visine i navedeni vrh se nadovezuje na planinski masiv planine Jahorina (Fotografija 4). Lokalitet nalazišta planinskog javora na Tvičijaku prostire se od 43° 72' 88 geografske širine do 18° 97' 53 geografske dužine. Populacije planinskog javora su pronađene na sjeveroistočnoj ekspoziciji i nadmorskoj visini od 1010 m.

PLANINSKI JAVOR - ROGATICA

1 : 10 000



Fotografija 4. Karta nalazišta planinskog javora na lokalitetu planine Tvičijak

Picture 4. Map of Balkan maple sites on the Tvičijak mountain location

Tabela 1. Deskriptivna statistika dendrometrijskih karakteristika planinskog javora na lokalitetu Trebević

Table 1. Descriptive statistics of dendrometric characteristics of Balkan maple at the Trebević site

Prsni prečnik (cm)		*Prirast (mm)*		*Visina (m)*	
Mean	18,25	Mean	48,9444444	Mean	13,6694444
Standard Error	1,2930676	Standard Error	2,09986562	Standard Error	0,54921039
Standard Deviation	7,75840558	Standard Deviation	12,5991937	Standard Deviation	3,29526235
Range	32	Range	54	Range	13,4
Minimum	6	Minimum	28	Minimum	6
Maximum	38	Maximum	82	Maximum	19,4
Sum	657	Sum	1762	Sum	492,1
Count	36	Count	36	Count	36
Confidence Level(95,0%)	2,62506678	Confidence Level(95,0%)	4,26295385	Confidence Level(95,0%)	1,11495637

MATERIALS AND METHODS - *Materijal i metode rada*

Prikupljanje podataka na terenu vršeno je na tri različita lokaliteta – Trebević, Jahorina i Tvičijak. Pregledom tri navedena lokaliteta pronađena su i obilježena sva stabla planinskog javora. Stabla su analizirana tokom mjeseca juna i jula 2021. godine. Na lokalitetu Trebević na nadmorskoj visini od 1540 m, analizom je obuhvaćeno 36 stabala, na lokalitetu Jahorina na nadmorskoj visini od 1570 m, obuhvaćeno je 31 stablo i na lokalitetu Tvičijak na nadmorskoj visini od 1010 m, analizirano je 8 stabala. Na pomenutim lokalitetima vršeno je prikupljanje sljedećih podataka:

- Obrojčavanje stabala na terenu i upisivanje koordinata lokaliteta, kao i kartografski prikaz sastojine
- Prikupljanje podataka o prečniku stabala uz upotrebu prečnice
- Prikupljanje podataka o visinama stabala uz upotrebu visinomjera (SUUNTO)
- Prikupljanje podataka o prirastu uz upotrebu Preslerovog svrdla, te izbrajanje godova na izvađenim izvrtcima i uvećavanjem za dva (2) kako bi dobili desetogodišnji prirast za navedeno stablo koje je predmet mjerenja.

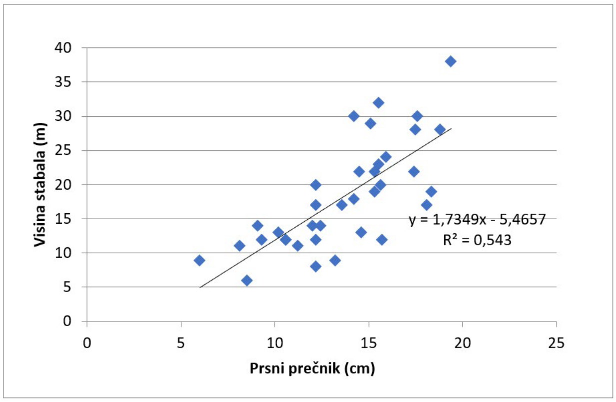
Statistička obrada podataka je izvršena u statističkom paketu STATGRAPHICS Centurion XVI i Microsoft Excel programu.

RESULTS AND DISCUSSION - *Rezultati i diskusija*

Na lokalitetima Jahorina, Trebević i Tvičijak analizom je obuhvaćeno ukupno 75 stabala planinskog javora. Visine stabala su se kretale od 6 m do 30,7 m (prosječno 18,4 m). Prsni prečnik analiziranih stabala se kretao od 6 cm do 85 cm (prosječno 46 cm), a desetogodišnji prirast od 26 mm do 82 mm (prosječno 54 mm).

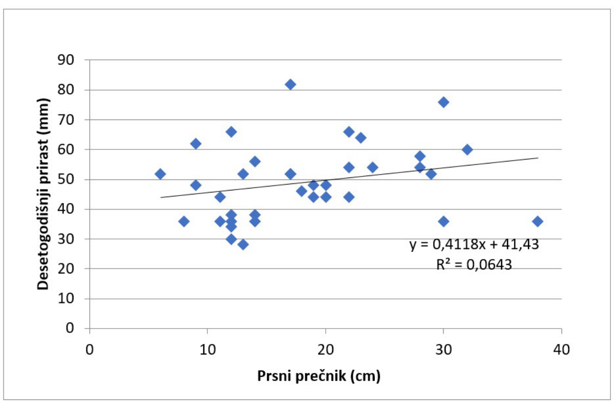
Obradom podataka na lokalitetu planine Trebević (tabela 1) je obuhvaćeno 36 stabala planinskog javora sa prsnim prečnikom u rasponu od 6 cm najniže vrijednosti do 38 cm najvećeg izmjerenog prečnika. Izmjerene visine na pomenutom lokalitetu kretale su se u rasponu od 6,0 metara do 19,4 metara koliko je iznosilo najviše stablo. Prirast se kretao u rasponu od 28 mm najniže vrijednosti do 82 mm najveće vrijednosti prirasta.

Analizom distribucije prsnog prečnika i visine stabala planinskog javora na lokalitetu Trebević (grafikon 1) izravnjavanjem srednjih vrijednosti, zaključujemo da stabla prečnika 15 cm postižu optimalne visine stabala koje u prosjeku postižu optimalne visine od 20 metara. Uporednom analizom desetogodišnjeg debljinskog prirasta i prsnog prečnika (grafikon 2) na lokalitetu Trebević, optimalne prosječne vrijednosti ostvarene su u debljinskom stepenu od 20 cm gdje desetogodišnji prirast iznosi 50 mm. Najniže postignute vrijednosti izmjerenog debljinskog prirasta iznose 27 mm za debljinski stepen od 10–20 cm, a najveće ostvarene vrijednosti nalaze se u debljinskom stepenu od 20–30 cm.



Grafikon 1. Distribucija prsnog prečnika i visine stabala planinskog javora na lokalitetu Trebević

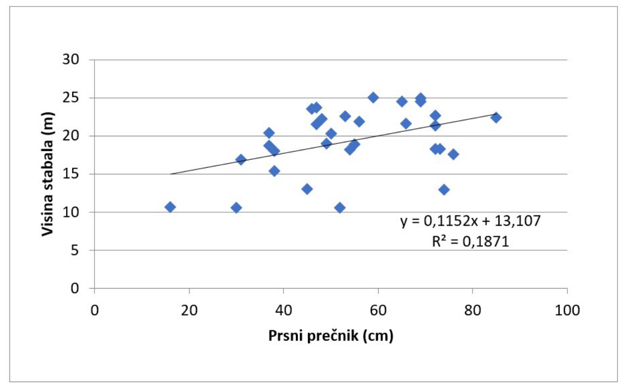
Graph 1. Distribution of diameter at breast height (dbh) and tree height of the Balkan maple trees at the Trebević site



Grafikon 2. Distribucija prsnog prečnika i desetogodišnjeg prirasta planinskog javora na lokalitetu Trebević

Graph 2. Distribution of diameter at breast height (dbh) and ten-year growth of the Balkan maple trees at the Trebević site

Obradom podataka na lokalitetu planine Jahorina (tabela 2) je obuhvaćeno 31 stablo planinskog javora sa prsnim prečnikom u rasponu od 16 cm najniže vrijednosti do 85 cm najvećeg izmjerenog prečnika. Izmjerene visine na pomenutom lokalitetu kretale su se u rasponu od 10,5 metara najniže stablo do 25,10 metara koliko je iznosilo najvisočije stablo. Prirast se kretao u rasponu od 26 mm najniže vrijednosti do 41 mm najveće vrijednosti prirasta.



Grafikon 3. Distribucija prsnog prečnika i visine stabala planinskog javora (Acer heldreichii) na lokalitetu Jahorina

Graph 3. Distribution of diameter at breast height (dbh) and tree height of the Balkan maple trees at the Jahorina site

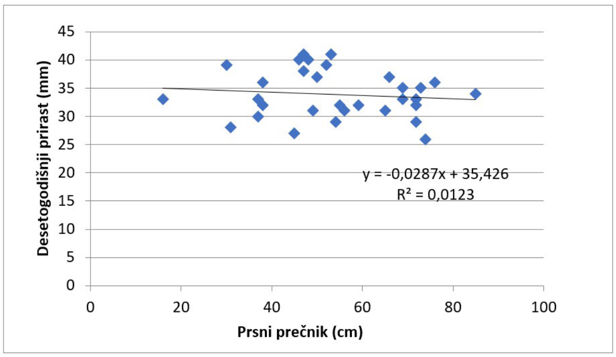
Analizom distribucije prsnog prečnika i visine stabala planinskog javora na lokalitetu Jahorina (grafikon 3) izravnjavanjem srednjih vrijednosti zaključujemo da stabla prečnika u debljinskom stepenu od 40–60 cm postižu optimalne visine stabala, koje u prosjeku postižu optimalne visine od 20 metara. Uporednom analizom desetogodišnjeg debljinskog prirasta i prsnog prečnika (grafikon 4) na lokalitetu Jahorina, ujednačeni su para-

Tabela 2. Deskriptivna statistika dendrometrijskih karakteristika planinskog javora (Acer heldreichii) na lokalitetu Jahorina

Graph 2. Descriptive statistics of dendrometric characteristics of Balkan maple at the Jahorina site

Prsni prečnik (cm)		*Prirast (mm)*		*Visina (m)*	
Mean	54,2258065	Mean	33,8709677	Mean	19,3516129
Standard Error	2,9118629	Standard Error	0,75168905	Standard Error	0,77514995
Standard Deviation	16,2125665	Standard Deviation	4,18522748	Standard Deviation	4,31585225
Range	69	Range	15	Range	14,6
Minimum	16	Minimum	26	Minimum	10,5
Maximum	85	Maximum	41	Maximum	25,1
Sum	1681	Sum	1050	Sum	599,9
Count	31	Count	31	Count	31
Confidence Level (95,0%)	5,9468174	Confidence Level (95,0%)	1,53515383	Confidence Level (95,0%)	1,58306739

metri, a optimalne prosječne vrijednosti ostvarene su u debljinskom stepenu od 60 do 80 cm gdje desetogodišnji prirast iznosi 35 mm. Najniže postignute vrijednosti izmjerenog debljinskog prirasta iznose 25 mm za prsni prečnik od 70 cm.

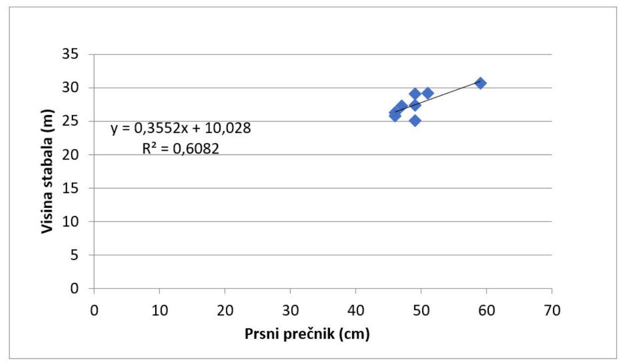


Grafikon 4. Distribucija prsnog prečnika i desetogodišnjeg prirasta planinskog javora (Acer heldreichii) na lokalitetu Jahorina

Graph 4. Distribution of diameter at breast height (dbh) and ten-year growth of the Balkan maple trees at the Jahorina site

Obradom podataka na lokalitetu planine Tvičijak (tabela 3) je obuhvaćeno 8 stabala planinskog javora sa prsnim prečnikom u rasponu od 46 cm najniže vrijednosti do 59 cm najvećeg izmjerenog prečnika. Izmjerene visine na pomenutom lokalitetu kretale su se u rasponu od 25,1 metara do 30,7 metara koliko je iznosilo najvisočije stablo. Prirast se kretao u rasponu od 39 mm najniže vrijednosti do 52 mm najveće vrijednosti prirasta.

Analizom distribucije prsnog prečnika i visine stabala planinskog javora na lokalitetu Tvičijak (grafikon 5) izravnjavanjem srednjih vrijednosti zaključujemo da stabla prečnika u debljinskom stepenu 40–50 cm postižu optimalne visine stabala koje u prosjeku postižu optimalne visine od 25 metara. Uporednom analizom desetogodišnjeg debljinskog prirasta i prsnog prečnika (grafikon 6) na lokalitetu Tvičijak, ujednačeni su parametri, a optimalne prosječne vrijednosti ostvarene su u debljinskom stepenu 40–50 cm gdje desetogodišnji prirast iznosi 47 mm. Najniže postignute vrijednosti izmjerenog debljinskog prirasta iznose 39 mm za prsni prečnik od 60 cm.



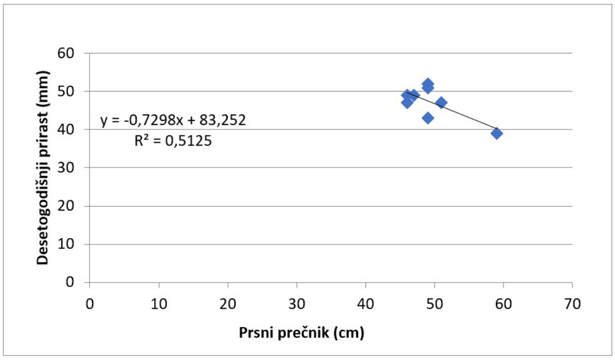
Grafikon 5. Distribucija prsnog prečnika i visine stabala planinskog javora (Acer heldreichii) na lokalitetu Tvičijak

Graph 5. Distribution of diameter at breast height (dbh) and tree height of the Balkan maple trees at the Tvičijak site

Tabela 3. Deskriptivna statistika dendrometrijskih karakteristika planinskog javora (Acer heldreichii) na lokalitetu Tvičijak

Table 3. Descriptive statistics of dendrometric characteristics of Balkan maple at the Tvičijak site

Prsni prečnik (cm)		*Prirast (mm)*		*Visina (m)*	
Mean	49,5	Mean	47,125	Mean	27,6125
Standard Error	1,48804762	Standard Error	1,51701657	Standard Error	0,67782148
Standard Deviation	4,20883425	Standard Deviation	4,29077083	Standard Deviation	1,91716867
Range	13	Range	13	Range	5,6
Minimum	46	Minimum	39	Minimum	25,1
Maximum	59	Maximum	52	Maximum	30,7
Sum	396	Sum	377	Sum	220,9
Count	8	Count	8	Count	8
Confidence Level (95,0%)	3,51867349	Confidence Level (95,0%)	3,58717418	Confidence Level (95,0%)	1,60279312



Grafikon 6. Distribucija prsnog prečnika i desetogodišnjeg prirasta (Acer heldreichii) na lokalitetu Tvičijak

Graph 6. Distribution of diameter at breast height and ten-year growth of the Balkan maple trees at the Tvičijak site

Primjenom ANOVA testa u statističkom paketu STATGRAPHICS utvrđeno je postojanje statističkih značajnih razlika u prosječnim vrijednostima prsnog prečnika, prirasta i visine uz vjerovatnoću od 95% (*p* = 0,000 - prsni prečnik, prirast, visina). S obzirom na to da je utvrđeno postojanje statističkih značajnih razlika za svaku od analiziranih dendrometrijskih karakteristika, provedena su višestruka testiranja primjenom Tukey HSD testa.

Tabela 4. Tukey HSD test – prečnik planinskog javora na 3 lokaliteta

Table 4. Tukey HSD test – diameter of breast hight of Balkan maple at three sites

	Count	Mean	Homogeno-us groups
Trebević	36	18,25	X
Tvičijak	8	49,5	X
Jahorina	31	54,2258	X
Contrast	**Sig.**	**Difference**	**+/- Limits**
Trebević - Jahorina	*	-35,9758	6,95079
Trebević - Tvičijak	*	-31,25	11,0881
Jahorina - Tvičijak		4,72581	11,2495

* označava statistički značajnu razliku

Prilikom korištenja Tukey HSD testa, možemo uočiti statističke značajne razlike u pogledu prečnika na datim lokalitetima. Homogene grupe su Jahorina i Tvičijak, te između njih nema statistički značajnih razlika. Zvjezdica je stavljena pored 2 para (Trebević-Jahorina, Trebević-Tvičijak), što ukazuje da ovi parovi pokazuju statistički značajne razlike na nivou pouzdanosti od 95,0%.

Tabela 5. Tukey HSD test – prirast planinskog javora na 3 lokaliteta

Table 5. Tukey HSD test – growth of Balkan maple at three sites

	Count	Mean	Homogenous groups
Jahorina	31	33,871	X
Tvičijak	8	47,125	X
Trebević	36	48,944	X
Contrast	**Sig.**	**Difference**	**+/- Limits**
Trebević - Jahorina	*	15,0735	5,44603
Trebević - Tvicijak		1,81944	8,68771
Jahorina - Tvičijak	*	-13,254	8,81417

* označava statistički značajnu razliku

Prilikom korištenja Tukey HSD testa, možemo uočiti statističke značajne razlike u pogledu prirasta na datim lokalitetima. Homogene grupe su Trebević i Tvičijak, te između njih nema statistički značajnih razlika. Zvjezdica je stavljena pored 2 para (Trebević-Jahorina, Jahorina-Tvičijak), što ukazuje da ovi parovi pokazuju statistički značajne razlike na nivou pouzdanosti od 95,0%.

Tabela 6. Tukey HSD test – visina planinskog javora na 3 lokaliteta

Table 6. Tukey HSD test – height of Balkan maple at three sites

	Count	Mean	Homogenous groups
Trebević	36	13,6694	X
Jahorina	31	19,3516	X
Tvičijak	8	27,6125	X
Contrast	**Sig.**	**Difference**	**+/- Limits**
Trebević - Jahorina	*	-5,68217	2,14633
Trebević - Tvičijak	*	-13,9431	3,42389
Jahorina - Tvičijak	*	-8,26089	3,47374

* označava statistički značajnu razliku

Nakon primjene Tukey HSD testa, uočavamo statističke značajne razlike u pogledu visina na datim lokalitetima. Zvjezdica je stavljena pored 3 para (Trebević-Jahorina, Trebević-Tvičijak, Jahorina-Tvičijak), što ukazuje da ovi parovi pokazuju statistički značajne razlike na nivou pouzdanosti od 95,0%.

Planinski javor je vrsta koja se javlja na različitim ekspozicijama, ali je na lokalitetu Trebevića prvenstveno zastupljen na hladnim i vlažnim sjevernim, a na području Jahorine i Tvičijaka na sjeveroistočnim područjima. Prema Milošević et al. (2019) najveću količinu i pokrivenost, kao i najveću dimenziju, planinski javor dostiže u subalpskom vegetacijskom pojasu i ovaj pojas se smatra najpogodnijim jer je vrsta koja je osjetljiva na uticaje tople klime, pa zauzima uglavnom skrivenu, sjevernu, sjeveroistočnu i istočnu ekspoziciju.

Šume javora su bile proučavane na različitim mjestima, uključujući Javor, Dvorište i najviši šumski pojas vegetacije zvan Zlatna dolina do Stanskog vrela. Šume se nalaze na velikim nadmorskim visinama od 1350 do 1600 m, uglavnom sastavljenim od krečnjaka, kvarcnog pješčenjaka i koluvijalnih naslaga. Prema Petronić et al. (2012) pokrivenost šuma se kreće od 60% do 80%, a visina vegetacije varira u zavisnosti od vrste šume, gdje u remontnim šumama, planinski javor dostiže visinu i do 30 metara, a u degradiranim oko 8 metara, sa pojedinačnim stablima preko 30 m visine. Prema istraživanjima Pandeva (2003) na planinama Balkanskog poluostrva *Acer heldreichii* Orph. raste u visinskoj zoni 900–2100 m, pojedinačno zalazi iznad gornje granice šumskog drveća. Doživi starost do 400 godina i dostiže visine do 30 m, a prečnike do 100 cm.

Istraživanjima Perović (2013) u Srbiji zapaženo je da planinski javor prvenstveno gradi zajednice sa subalpskom bukvom, a vrlo rijetko sa smrčom. Pojava zajednice planinskog javora i smrče na Jahorini jasno govori o manjoj frigorifilnosti planinskog javora u odnosu na smrču i njegovog približavanja u ovom pogledu bukvi. Tako Kojić et al. (1994, 1997) svrstavaju planinski javor i bukvu u grupu mezotermnih vrsta, dok smrču tretiraju kao frigorifilno-mezotermnu vrstu. S obzirom na to da planinski javor dobro podnosi kasne proljetne mrazeve, to mu omogućava da se diže na veće nadmorske visine, te tako na nekim planinama izgrađuje uzak pojas iznad pojasa subalpijske bukve ili se javlja u čistim sastojinama na hladnijim staništima u pojasu subalpijskih bukovih šuma (Lakušić 1989).

Izrazito smanjena populacija planinskog javora se može objasniti i istraživanjima (Petronić et al. 2012) koja kažu da se populacija planinskog javora na lokalitetu Jahorine znatno smanjenila zbog česte sječe u svrhu formiranja ski-staza, žičara i dalekovoda. Osim toga, prethodni ratovi su takođe ostavili vidljiv trag na ovim prostorima (Petronić et al. 2012).

Da bi se planinski javor očuvao, potrebno je da očuvamo područja naših planina kako bi se mogao omogućiti kontinuiran opstanak šumske vegetacije.

CONCLUSIONS - *Zaključak*

Na terenu su proučavane dendrometrijske karakteristike planinskog javora na lokalitetima Trebević, Jahorina i Tvičijak. Pregledom tri navedena lokaliteta pronađena su i obilježena sva stabla planinskog javora. Visine stabala su se kretale od 6 m do 30,7 m (prosječno 18,4 m). Prsni prečnik analiziranih stabala se kretao od 6 cm do 85 cm (prosječno 46 cm), a desetogodišnji prirast od 26 mm do 82 mm (prosječno 54 mm).

Analizom distribucije prsnog prečnika i visine stabala planinskog javora na lokalitetu Trebević izravnjavanjem srednjih vrijednosti zaključujemo da stabla prečnika 15 cm postižu optimalne visine od 20 metara. Na lokalitetu Jahorina zaključujemo da stabla prečnika u debljinskom stepenu od 40–60 cm postižu optimalne visine stabala koje u prosjeku iznose 20 metara, a na lokalitetu Tvičijak izravnjavanjem srednjih vrijednosti zaključujemo da stabla prečnika u debljinskom stepenu 40–50 cm postižu optimalne visine stabala koje u prosjeku postižu optimalne visine od 25 metara.

Uporednom analizom desetogodišnjeg debljinskog prirasta i prsnog prečnika na lokalitetu Trebević, optimalne prosječne vrijednosti ostvarene su u debljinskom stepenu od 20 cm gdje desetogodišnji prirast iznosi 50 mm, na lokalitetu Jahorina optimalne prosječne vrijednosti ostvarene su u debljinskom stepenu 60–80 cm gdje desetogodišnji prirast iznosi 35 mm, dok na lokalitetu Tvičijak optimalne prosječne vrijednosti ostvarene su u debljinskom stepenu 40–50 cm gdje desetogodišnji prirast iznosi 47 mm.

Statističkim analizama je utvrđeno postojanje statističkih značajnih razlika u prosječnim vrijednostima prsnog prečnika, prirasta i visine uz vjerovatnoću od 95% na navedena tri lokaliteta.

Planinski javor je vrsta koja se javlja na različitim ekspozicijama, ali je na lokalitetu Trebevića prvenstveno zastupljen na hladnim i vlažnim sjevernim, a na području Jahorine i Tvičijaka na sjeveroistočnim područjima.

Ova vrsta ima kvalitetno drvo, te veliki značaj u smislu zaštite zemljišta od erozije, poboljšanja ekoloških uslova za opstanak drugih biljnih vrsta, a uz to ima i izražena dekorativna svojstva. Kao posljedica sve češćih neplanskih sječa u svrhu formiranja ski-staza, žičara i dalekovoda na našim planinama, planinski javor sve više pronalazimo u manjim fragmentima ili pojedinačno.

Sva dalja istraživanja ove vrste će imati veliki značaj ako se ima na umu da planinski javor ima sposobnost rasta u uslovima u kojima samo mali broj vrsta drveća može da opstane, zbog čega ima veliki ekološki značaj na prirodnim nalazištima.

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SUMMARY

The results of dendrometric characteristics of the Balkan maple are presented in the paper for the mountain locations of Trebević, Jahorina, and Tvičijak in the vicinity of Rogatica. Various authors have provided an overview of the known Balkan maple sites in Bosnia and Herzegovina and some surrounding areas: Jahorina, Trebević, Klek near Prača, Kmur near Foča, Radomišlje, Treskavica, Zelengora, Volujak, Maglić, and Bjelašnica near Gacko. By reviewing the three mentioned research locations, all Balkan maple trees were found and marked. A total of 36 trees were analyzed in the Trebević location, 31 trees in Jahorina, and 8 trees in Tvičijak. The Balkan maple populations were found on the northern and northeastern exposure of the surveyed areas at altitudes of up to 1570m, and according to previous research, the largest quantity and coverage, as well as the largest dimension of Balkan maple were found in the subalpine vegetation zone where it mostly occupies a hidden, northern, northeastern, and eastern exposure. The height of Balkan maple trees ranged from 6 m to 30.7 m (average 18.4 m), while the diameter at breast height ranged from 6 cm to 85 cm (average 46 cm), and the ten-year increment ranged from 26 mm to 82 mm (average 54 mm). By analyzing the distribution of diameter and height of Balkan maple trees at different locations, it was concluded that trees with a diameter of 15 cm reach optimal heights of 20 meters on Trebević, while on Jahorina, trees with a diameter in the thickness degree of 40-60 cm reach optimal heights of 20 meters. On Tvičijak, optimal tree heights are achieved with trees with a diameter in the thickness degree of 40-50 cm, which on average reach a height of 25 meters. Optimal values for the thickness degree of trees and ten-year increment are presented at three locations: Trebević (20 cm - 50 mm), Jahorina (60-80cm - 35mm), and Tvičijak (40-50cm - 47mm). Statistical tests in the STATGRAPHICS software showed the existence of statistically significant results. Given that the Balkan maple tolerates late spring frosts well, it can grow at higher altitudes, building a narrow belt above the subalpine beech belt on some mountains or appearing in pure stands in cooler habitats in the subalpine beech forest zone. The extremely reduced population of Balkan maple on Jahorina can be explained by frequent logging for the purpose of forming ski slopes, cable cars, and power lines, as well as the consequences of previous wars. To preserve the Balkan maple, it is necessary to preserve the areas of our mountains to enable the continuous survival of the forest vegetation.

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REVIEW PAPER

Genus *Abies* Mill. (Pinaceae) as the source of plant antimicrobials: A Review

Rod *Abies* Mill. (Pinaceae) kao izvor biljnih antimikrobnih supstanci: Pregled

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ABSTRACT

Antimicrobial resistance is one of the major global health problems and it's related to the enormous number of human deaths. The occurrence and severity of infections caused by microbial pathogens illustrate the need for the identification and characterization of novel antimicrobial agents of natural origin. This review discusses a well-known coniferous genus *Abies* Mill. in terms of antimicrobial potential. Data regarding the antibacterial, antifungal, and antiviral properties of *Abies* species were collected and summarized in this review. It was found that 13 different *Abies* species are recognized as potential sources of antimicrobial compounds. The most investigated species was *A. spectabilis* (syn. *A. webbiana*), followed by *A. alba*, *A. cilicica*, *A. sibirica*, *A. nordmanniana*, *A. numidica*, *A. koreana*, *A. balsamea*, *A. holophylla*, and *A. concolor*. Individual studies on *A. firma*, *A. beshanzuensis*, and *A. cephalonica* were also taken into account. The largest number of analyzed results were related to the antibacterial activity of *Abies*-derived products, but studies on antifungal, and particularly antiviral capacity were also noted. The most investigated products were essential oils and extracts. The broadest antimicrobial activity was observed for *A. cilicica*. This study noted that some endemic and endangered *Abies* species were being used for antimicrobial purposes. In that term, the rationalization of the sampling practices and the implementation of the conservation activities are of great importance. This review represents a comprehensive overview of the current knowledge on the antimicrobial potential of the genus *Abies*.

Key words: *Abies, Antimicrobial activity, Antimicrobial resistance, Fir, Plant antimicrobials, Review, Secondary metabolites.*

INTRODUCTION - *Uvod*

Antimicrobial resistance (AMR) is one of the most challenging problems of global health in the 21st century (Hernando-Amado *et al.*, 2019). According to O'Neill (2016), AMR is related to 750,000 annual human deaths worldwide, and by the year 2050, that number could increase up to 10 million. As humanity, we are indeed faced with the lack of new antimicrobials, the rise of AMR, the toxicity of synthetic antimicrobial drugs, and their many potential side effects, as well as the economic burden that is unavoidable in the constant race with microbes to develop efficient and affordable medicines. In the abovementioned issues, plants could represent a potential solution (Chassagne *et al.*, 2021), since they produce secondary metabolites, well-known for their bioactive capacity.

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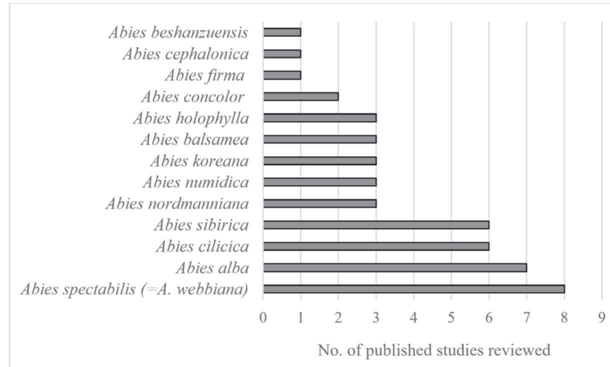
Coniferous plants, comprising eight families, 70 genera, and about 630 species distributed worldwide, are considered an important source of bioactive phytochemicals (Macovei *et al.*, 2023). According to Garzoli *et al.* (2021), the family Pinaceae is the largest family of non-flowering seed plants and includes 11 genera and approximately 230 species. Genus *Abies* Mill. encompasses approximately 50 species, with wide distribution in the Northern Hemisphere, especially within the northern boreal forest zone (Debreczy & Rácz, 2011). The largest number of *Abies* species live in the temperate zone, while a few of them occurs in subtropical habitats (Xiang *et al.*, 2007). Yang *et al.* (2008) stated that around 300 components are isolated from 19 *Abies* species. These compounds are mostly terpenoids, flavonoids, and lignans, followed by phenols, steroids, and other minor constituents. Different products derived from *Abies* species could be used for medicinal purposes, but one of the most frequently used are extracts and essential oils. The crude extracts and individual metabolites possess various bioactive properties including antitumor, antimicrobial, anti-ulcerogenic, anti-inflammatory, antihypertensive, etc. (Yang *et al.*, 2008), as well as the essential oils due to the richness in their chemical composition (Garzoli *et al.*, 2021).

MATERIAL AND METHODS – *Materijal i metode*

This review discusses the genus *Abies* in terms of antimicrobial potential. Despite the fact that there are individual published results regarding the antimicrobial activity of particular *Abies* species, to the best of our knowledge there is no systematic overview that debates the antibacterial, antifungal, and antiviral properties of the genus *Abies* in a comprehensive manner. Available data regarding the antimicrobial potential of *Abies* species were extracted from scientific databases Web of Science, Scopus, and PubMed, by using the search terms such as: "Abies", "antimicrobial activity", "antimicrobial resistance", "phytochemical composition", and "plant antimicrobials".

RESULTS AND DISCUSSION – *Rezultati i diskusija*

This review revealed that 13 *Abies* species were recognized in terms of antimicrobial potential. The total number of published studies for each species that is taken into consideration is presented in Graph 1.



Graph 1. Number of published studies about the antimicrobial activity of *Abies* species reviewed in this paper

Grafikon 1. Broj publikacija o antimikrobnom djelovanju Abies *vrsta analiziranih u ovom radu*

Details regarding the antimicrobial potential of particular species are presented below. Species are listed in accordance with their phylogenetic similarity (Xiang *et al.*, 2018).

Abies alba Mill.

Abies alba, known as the European Fir or Silver Fir is native to the mountains of Europe, but successfully cultivated in North America. It occurs at altitudes of 300 to 1,700 m, on mountains with rainfall over 1,000 mm per year (Simonetti & Simonetti, 1990; Farjon, 2017). Bağci and Diğrak (1996) reported a modest antibacterial activity of the essential oil (EO) made from *A. alba* twigs. Broznić *et al.* (2018) investigated the antibacterial properties of the fir honeydew honey against *Staphylococcus aureus*, *S. epidermidis*, and *Acinetobacter baumannii*. All strains were sensitive to the tested compound, with *Staphylococcus* strains being more susceptible (MIC values ranged from 0.0125 to 0.025 g/ml). This study highlighted many bioactive polyphenol compounds such as chrysin, galangin, quercetin, kaempferol, acacetin, pinocembrin, pinobanksin, caffeic acid, and apigenin. Truchan *et al.* (2019) observed the antibacterial effects of *A. alba* EO against several pathogens and noted very large inhibition zones: *Escherichia coli* (25.7 ±1.13 mm), *S. aureus* (23.8 ±1.25 mm), *Pseudomonas aeruginosa* (22.4 ±1.1 mm), and *Klebsiella pneumoniae* (19.4 ±0.98 mm). Similarly, Salamon *et al.* (2019) reported the antibacterial activity of *A. alba* EO against *E. coli*, *Enterococcus faecalis*, and *Candida albicans*, with the excessive activity observed against fungi, where the zone of inhibition was 30.00±1.25 mm. This EO was also effective against the clinical strain of *C. albicans*. These results could be related to the compounds such as α-pinene, boranyl acetate, borneol, and limonene. An earlier investigation by Yang *et al.* (2009) revealed some constituents of *A. alba*

EO: bornyl acetate, camphene, 3-carene, tricyclene, limonene, α-pinene, caryophyllene, β-phellandrene, borneol, bicyclo[2.2.1]hept-2-ene,2.3-dimethyl, and α-terpinene. The presented results are in accordance with Garzoli *et al.* (2021), who detected the most abundant components of the liquid phase of *A. alba* EO: α-pinene, β-pinene, limonene, and γ-terpinene. This EO exhibited antibacterial activity against *E. coli*, *Pseudomonas fluorescens*, *Acinetobacter bohemicus*, *Kocuria marina*, and *Bacillus cereus*. Values of the minimum inhibitory concentration and the minimum bactericidal concentration (MIC and MBC) were 51.28 mg/ml for *E. coli*, *P. fluorescens*, and *K. marina*, while lower MIC and MBC values were noted for *A. bohemicus* and *B. cereus* (12.82 mg/ml and 25.64 mg/ml, respectively). The MBC/MIC ratio defined the *A. alba* EO as bactericidal against all tested bacterial strains.

Abies cilicica **(Antoine et Kotschy) Carrière**

Abies cilicica (Cilician Fir) occurs in the mountains adjacent to the northeastern Mediterranean coast of Turkey, Syria, and Lebanon (Gardner & Knees, 2013). This species is dominant in the Abieti-Cedrion phytocoenosis, a type of forest that occurs between 800 and 2,100 m elevation. The annual precipitation is typically 1,000-1,500 mm, mostly falling in winter (Boydak, 2007).

Bağci and Diğrak (1996) investigated the antimicrobial activity of essential oils made from twigs of *A. cilicica* subsp. *cilicica* and *A. cilicica* subsp. *isaurica* against series of microorganisms: *E. coli*, *Bacillus megaterium*, *B. cereus*, *B. subtilis*, *B. brevis*, *P. aeruginosa*, *Listeria monocytogenes*, *K. pneumoniae*, *Enterobacter aerogenes*, *S. aureus*, *Saccharomyces cerevisiae*, and *C. albicans*. This study recorded a very high antimicrobial effect of the tested EOs, with stronger antifungal potential, and low activity against the Gram-negative pathogen *E. coli*. The main components of the *A. cilicica* subsp. *cilicica* EO are δ-3-carene, α-pinene, longipinene, β-caryophyllene, α-humulene, and germacrene D (Bağci & Diğrak, 1996). Kizil *et al.* (2002) proved the antimicrobial potential of the resins obtained from the roots and stems of *A. cilicica* on a panel of microorganisms: *S. aureus*, *Streptococcus pyogenes*, *Bacillus thurigiensis*, *B. brevis*, *B. subtilis*, *B. megatherium*, *B. cereus*, *P. aeruginosa*, *E. coli*, and *C. albicans*. Results suggested that increasing the resin concentration (from 40 to 80 μg per disk) led to the formation of broader inhibition zones. Later investigation by Dayisoylu *et al.* (2009) tested the antimicrobial properties of the EO from the resin of the cones of *A. cilicica* subsp. *cilicica* and included a wide list of microbial species: *Corynebacterium xerosis*, *B. brevis*, *B. megatherium*, *B. cereus*, *Mycobacterium smegmatis*, *P. aeruginosa*, *S. aureus*, *K. pneumoniae*, *E. faecalis*, *Micrococcus luteus*, *E. coli*, *Kluyveromyces fragilis*, *Rhodotorula rubra*, and *S. cerevisiae*. Interestingly, all strains except for *E. coli* were successfully inhibited by this EO. The values of minimum inhibitory concentration (MIC) of EO for inhibited bacteria were in the range of 0.50-3.50 μg/ml and for yeasts 0.50-1.75 μg/ml. The EO from the resin of the investigated plant contains limonene, β-pinene, α-pinene, and myrcene, with limonene being the most effective in terms of antibacterial potential, and myrcene as an antifungal agent. The aqueous and ethanolic extracts of resin obtained from cones of *A. cilicica* subsp. *isaurica* were investigated in terms of antimicrobial potential by Yavaşer *et al.* (2015). Activity is proven only for the ethanolic extract against *S. aureus* (11 mm), *B. cereus* (17 mm), and *M. luteus* (18 mm). However, there were no inhibition zones in the case of *E. faecalis*, *E. coli*, and *L. monocytogenes*. The resins are rich in terpenes and extracts may contain terpenoids, steroids, tannins, glycosides, anthraquinones, saponins, flavonoids, alkaloids, etc. The antibacterial activity of the ethereal extract made from *A. cilicica* is recorded by Erylmaz *et al.* (2016), against *S. aureus* (including methicillin-resistant strain, MRSA), *B. subtilis*, *E. coli*, *P. aeruginosa*, and *K. pneumoniae*, while the same substance did not show antifungal properties against *C. albicans*. The crude extracts from the leaf and flowering cones of *A. cilicica* subsp. *cilicica* were active against *E. faecalis*, *Proteus vulgaris*, *K. pneumoniae*, *C. albicans*, and *Aspergillus niger*. The growth of bacteria and fungi isolates was inhibited by methanolic, ethanolic, and acetonic extracts to different degrees, according to the tested organisms, plant fraction, and examined solvent (Saleh & Al-Mariri, 2016).

Abies nordmanniana **(Steven) Spach**

Abies nordmanniana (Nordmann Fir or Caucasian fir) is indigenous to the mountains south and east of the Black Sea, in Turkey, Georgia, and the Russian Caucasus. Typically, it occurs at altitudes of 900 to 2,200 m on mountains characterized by precipitation of over 1,000 mm (Tarkhnishvili *et al.*, 2011). In the study of Bağci and Diğrak (1996), the essential oils of two subspecies were investigated *A. nordmanniana* subsp. *nordmanniana* and *A. nordmanniana* subsp. *bornmiielleriana*, and proven for their high antimicrobial activity against *Bacillus megaterium*, *B. brevis*, *B. subtilis*, *Staphylococcus aureus*, *Pseudomonas aeruginosa*, *Enterobacter aerogenes*, *Klebsiella pneumoniae*, and *Listeria monocytogenes*. Antimicrobial activity of the methanolic and ethanolic extracts of leaves, cones, twigs, and stem barks of *A. nordmanniana* subsp. *equi-trojani* were detected against *Mycobacterium smegmatis*, *B. subtilis*, *Salmonella typhimurium*, *Sarcina lutea*, *E. coli*, *S. aureus*, *Candida utilis*, and *S. cerevisiae* in the research of Sakar *et al.* (1998). Observed effects are in relation to diterpenoids, flavonoids, and tannin precursors. Erylmaz *et al.* (2016) noted relatively narrow antibacterial activity of *A. nordmanniana* ethereal extract, but interestingly, inhibition was observed against Gram-negative *E. coli* and *P. aeruginosa*, known for their extended antimicrobial resistance. The same study debates the antimicrobial activity of species refer as *Abies equi-trojani*, but according to the Euro+Med PlantBase, this is the synonym of *A. nordmanniana* subsp. *equi-trojani*. The ethereal extract showed antibacterial activity against *B. subtilis* and *P. aeruginosa*.

Abies numidica de Lannoy ex Carrière

Abies numidica is an endemic Algerian plant, growing in a high-altitude Mediterranean climate at 1,800-2,004 m with an annual precipitation of 1,500 to 2,000 mm (Yahi *et al.*, 2011). Tlili Ait Kaki *et al.* (2012) found that pure essential oil of *A. numidica* was not active against investigated microorganisms, while particular dilution performed activity against MRSA, *E. coli*, *K. pneumoniae*, *P. aeruginosa*, *Acinetobacter* sp., and *S. epidermidis*. Inhibition zones were detected for all the investigated microorganisms at the dilution of 1/1000 (using dimethyl sulfoxide). The essential oil of *A. numidica* used in the investigation of Ramdani *et al.* (2014) was very active against *B. cereus*, *E. coli*, and *E. faecalis*. Modest activity was noted for *S. aureus*, *S. epidermidis*, and *M. luteus*, while low antibacterial activity was described for *K. pneumoniae*. Antifungal effects were very strong against *S. cerevisiae*. Unlike essential oils, Mostefa *et al.* (2016) investigated the phytochemical composition and antimicrobial potential of *A. numidica* hydro-methanolic cones extract. Chromatography revealed several new chemical compounds for this species, mainly abietane diterpenes. Investigated extract, as well as the individual compounds, performed antibacterial activity against *B. subtilis* (MIC=62.50 μg/ml), *E. faecalis*, *S. aureus*, *M. luteus*, and *Listeria innocua* (MIC≤250 μg/ml).

Abies sibirica Ledeb.

Abies sibirica or Siberian Fir is native to the taiga ecosystems in Siberia, Turkestan, Xinjiang, Mongolia, and Heilongjiang. The species inhabits a cold boreal climate at elevations of 1,900-2,400 m (Katsuki *et al.*, 2011) where average annual precipitation exceeds 600 mm (Bazhina, 2014). As one of the dominant tree species in European Russia, as well as of the Siberian taiga, it has been used in conventional and traditional medicine since ancient times (Makarova *et al.*, 2013). *Abies sibirica* is recognized as a source of agents with anti-inflammatory, antimicrobial, wound healing, regenerating, and antifungal properties (Ayupova *et al.*, 2014). Noreikaitė *et al.* (2017) showed that EO from *A. sibirica* exhibits antifungal activity against *C. albicans*. Truchan *et al.* (2019) detected the mild antibacterial effects of essential oil of this plant species against *P. aeruginosa* and MRSA strain, with clear inhibition zones of 9.40±0.1 mm, and 9.40±0.25 mm, respectively. The antiviral potential of polyprenols from *A. sibirica* is proven against the Influenza virus (Boldyrev *et al.*, 2000; Safatov *et al.*, 2000; Safatov *et al.*, 2005). Furthermore, Sokolova *et al.* (2018) investigated compounds like borneol and camphor from this plant in order to design novel inhibitors for the Vaccinia virus.

Abies koreana E.H.Wilson

Abies koreana or Korean Fir is endemic species, native to the higher mountains of South Korea and occurs in habitats at 1,000 to 1,900 m of altitude, characterized by high rainfall, with cool and humid summers and heavy winter snowfall (Kim *et al.*, 2011). Bağci and Diğrak (1996) observed the extensive antimicrobial potential of the essential oil of this plant species against different microorganisms, including Gram-positive and Gram-negative bacteria, as well as fungi. Furthermore, the antibacterial activity of *A. koreana* EO against several bacterial strains is reported by Jeong *et al.* (2007). The results obtained from the disk diffusion method indicated that tested EO exhibits a variable degree of antibacterial activity on different tested strains, with *Staphylococcus epidermidis* being the most susceptible strain, followed by MSSA and MRSA, *Staphylococcus haemolyticus*, *S. simulans*, and *S. flexneri*. Gram-negative strains displayed variable degrees of susceptibility, with the maximum activity observed against *E. coli* and *P. aeruginosa*. Oh *et al.* (2007) identified 47 compounds from the *A. koreana* essential oils, with limonene being the most abundant, followed by bornyl acetate, α-pinene, camphene, β-himachalene, β-myrcene, γ-selinene, γ-gurjunene, β-eudesmene, β-pinene, and other minor constituents. The same investigation confirmed the inhibitory activity of this EO against *E. coli*, *S. epidermidis*, and *C. albicans*. *S. epidermidis* was more sensitive in comparison to *E. coli*, while investigated EO led to extensive inhibition of *C. albicans* with the inhibition zones of 34.0±2.83 mm.

Abies balsamea (L.) Mill.

Abies balsamea, known as the Balsam Fir, is species native to most of eastern and central Canada and the northeastern USA (Farjon, 2013a). This species is shade tolerant and grow in cool climates, with a mean annual temperature of 4 °C, with consistent moisture at their roots (Walters & Reich, 2000). Pichette *et al.* (2006) investigated the chemical profile and antimicrobial activity of *A. balsamea* essential oil. The analysis revealed β-pinene to be the main component, followed by δ-3-carene, α-pinene, and bornyl acetate. Tested EO showed antibacterial activity against *S. aureus* (MIC value was determined at 56 μg/ml), while individual compounds were effective against *E. coli* as well. The antibacterial potential of the *A. balsamea* needle extract was investigated by Vandal *et al.* (2015), while Coté *et al.* (2016) studied the antibacterial effects of *A. balsamea* oleoresin. The latter substance was effective against *S. aureus*, including the MRSA strain. According to this research, oleoresin is mainly composed of monoterpenes, sesquiterpenes, and diterpenes. Resin acids, isopimaric and levopimaric acids detected in the sample are also related to the antibacterial properties of the whole oleoresin.

Abies concolor (Gordon) Lindl. ex Hildebr.

Abies concolor, commonly known as the White Fir, is species native to the mountains of western North America, with typical occurrence at elevations between 900 and 3,400 m (Farjon, 2013b). The essential oil of this species is tested by Bağci and Diğrak (1996) against various microorganisms, but antimicrobial activity was not detected. Nevertheless, the antibacterial properties of the seed and cone EO of *A. concolor* were observed in the study of Wajs-Bonikowska *et al.* (2017) against *S. aureus*, *Enterococcus faecium*, *E. faecalis*, *E. coli*, and *K. pneumoniae*. Obtained results showed that seed EO was more efficient in comparison to cone EO. This investigation also debates the chemical profile of the investigated EOs. As the main constituent was noted β-pinene, followed by limonene, camphene, β-phellandrene, and α-pinene.

Abies spectabilis (D.Don) Mirb. /syn. *Abies webbiana* (Wall ex D.Don) Lindl./

Abies spectabilis (East Himalayan Fir) is the dominant tree in the forests of the central and western Himalayas, especially from 3,000 m to 4,050 m, with occasional occurrences on ridges below this height (Thomas, 2019). The study performed by Vishnoi *et al.* (2007) investigated the antimicrobial activity of *A. spectabilis* methanolic extract in the range of 625 μg/ml to 5 mg/ml, and obtained significant results against several bacterial and fungal species: *S. aureus*, *S. epidermidis*, *M. luteus*, *E. coli*, *Salmonella typhi*, *Vibrio cholerae*, *Shigella dysenteriae*, *A. niger*, and *C. albicans*. The inhibition zones were larger with the increased concentration of the extract. Constituents that are probably related to the observed antibacterial activity are abiesin, methyl betuloside, and betuloside identified in the leaves. Ambre *et al.* (2019) investigated compounds present in *A. spectabilis* chloroform leaf extract that are responsible for inhibitory activity against *S. aureus*. Authors identified seven metabolites, namely betuloside, 2,7-dihydroxy-4'-methoxyisoflavanone, genistein 7-O-beta-D-glucoside, β-sitosterol, abietane, coniferol, and 1-(3,4-dihydroxyphenyl)-1-decene-3,5-dione-Pos. Previous studies also recorded the antimicrobial potential of this species. Donovan *et al.* (2009) noted that genistein 7-O-beta-D-glucoside-isoflavone possesses antiviral activity; Ododo *et al.* (2016) presented an inhibitory effect of β-sitosterol against *S. aureus* and *E. coli*; González (2015) reported the antibacterial activity of diterpene abietane against *S. aureus*, *B. subtilis*, *P. aeruginosa*, and *E. coli*; Makwana *et al.* (2015) noted activity of monolignol coniferol on *E. coli*. These results are in accordance with the investigation of Timothy *et al.* (2021) who tested the ethanolic extract of *A. spectabilis* on various microorganisms: *S. aureus*, *Streptococcus mutans*, *E. faecalis*, and *C. albicans*, which exhibited very good antimicrobial properties. Furthermore, a recent study by Gautam *et al.* (2022) on ethanolic extract made from *A. spectabilis* leaves showed a wide antimicrobial range of activity, with fungal species being more susceptible to the tested compound in comparison to the bacteria. The authors stated that high phenolic content could be in relation to the described properties.

Abies holophylla Maxim.

Abies holophylla or Manchurian Fir is native to a mountainous region of northern Korea (Katsuki *et al.*, 2013). This species has pronounced heat tolerance, and it is exceptionally winter hardy, capable of withstanding temperatures up to -34 °C. Manchurian fir grows in the mountains, but also at lower elevations and in valleys where it is exposed to hot summer temperatures (Meyer, 2010). The investigation of Lee and Hong (2009) revealed 38 compounds that mainly comprised *A. holophylla* essential oil, with the main constituents being bicyclo[2.2.1]heptan-2-ol, δ-3-carene, α-pinene, camphene, limonene, β-myrcene, trans-caryophyllene, and α- bisabolol. This EO exhibited antibacterial activity against *E. coli*, *Klebsiella oxytoca*, *B. subtilis*, and *S. aureus*. Furthermore, when MIC values were tested, promising results were gained in the cases of *Enterobacter aerogenes*, *E. cloacae*, *K. pneumoniae*, *B. subtilis*, *Candida glabrata*, and *Cryptococcus neoformans*. Lee and Hong (2009) observed the antibacterial effects of *A. holophylla* EO, with interesting results of stronger inhibition of the Gram-negative species such as *E. coli* and *K. pneumoniae*. Later research by Lee *et al.* (2014) confirmed the antibacterial activity of EO against *K. pneumoniae*, *Haemophillus influenzae*, *S. pyogenes*, *Streptococcus pneumoniae*, and *Neisseria meningitidis*. As the major constituents α-pinene,

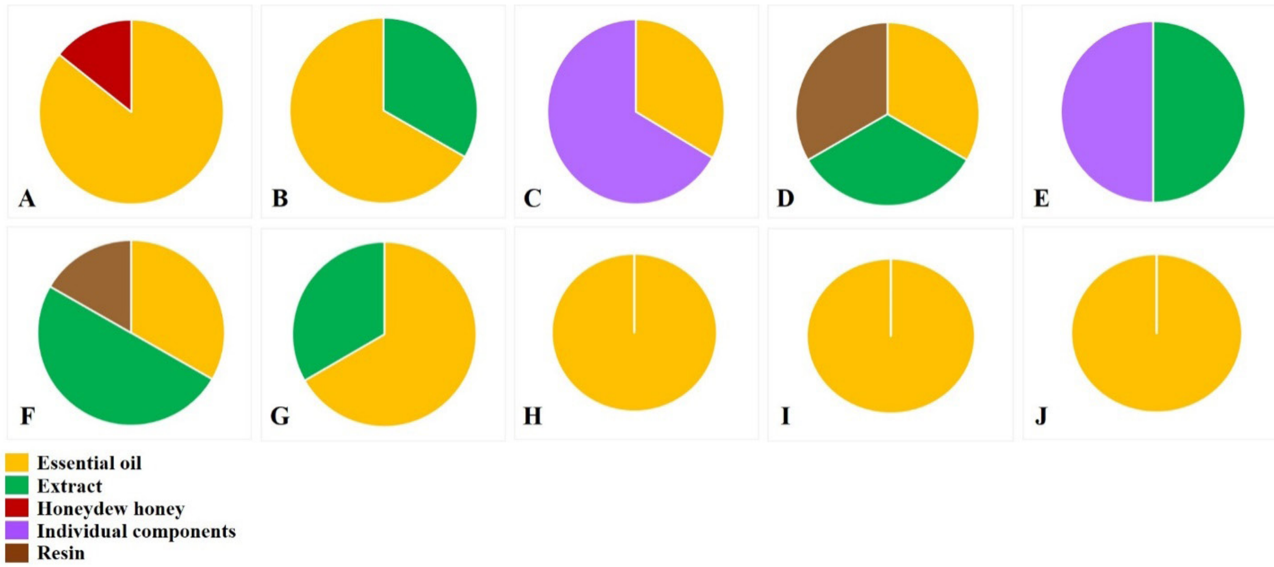


Figure 1. Plant products of *Abies* species investigated in terms of antimicrobial activityA: *A. alba*; B: *A. nordmanniana*; C: *A. sibirica*; D: *A. balsamea*; E: *A. spectabilis* (=*A. webbiana*); F: *A. cilicica*; G: *A. numidica*; H: *A. koreana*; I: *A. concolor*; J: *A. holophylla*

Slika 1. Biljni produkti Abies *vrsta istraživani u smislu antimikrobne aktivnosti A: A. alba; B: A. nordmanniana; C: A. sibirica; D: A. balsamea; E: A. spectabilis (=A. webbiana); F: A. cilicica; G: A. numidica; H: A. koreana; I: A. concolor; J: A. holophylla*

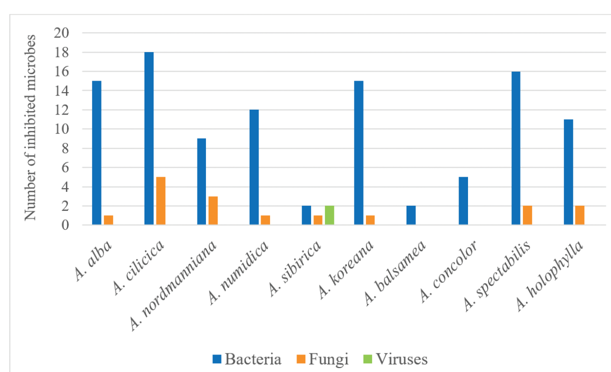
camphene, β-pinene, 3-carene, limonene, bornyl acetate, borneol, β-caryophyllene, α-caryophyllene, caryophyllene oxide, and α-bisabolol were identified.

There is also some isolated data regarding the antimicrobial activity of other *Abies* species, such as *Abies firma* Siebold & Zucc. (Bağci & Diğrak, 1996), *Abies beshanzuensis*M.H.Wu (Hu *et al.*, 2016), and *Abies cephalonica* Loudon (Tsasi *et al.*, 2022). Furthermore, a recent study by Baser *et al.* (2023) debates *Abies*-derived compounds as antiviral agents, including the inhibition of the novel virus SARS-CoV-2.

This review showed that the most investigated products in terms of antimicrobial potential were essential oils and extracts. Additionally, the antimicrobial activity of resin, honeydew honey, and some individual chemical compounds was also investigated. Studied products for each species are presented in Figure 1. The representation in Figure 1 refers to those *Abies* species for which more than one study on antimicrobial activity was available.

Overall analyses revealed that different products derived from *Abies* species have proven inhibitory activity against 44 Gram-positive and Gram-negative species of bacteria, including some multidrug-resistant strains. Furthermore, inhibitory effects were detected against eight species of fungi and two viruses (Table 1).

The broadest antimicrobial activity was noted in *A. cilicica*, with proven inhibitory action against 18 bacteria and five fungi. Very high antimicrobial properties were observed in *A. spectabilis*, *A. alba*, *A. koreana*, *A. numidica*, and *A. holophylla* (Graph 2).



Graph 2. Antimicrobial capacity observed in *Abies* species

Grafikon 2. Antimikrobni kapacitet uočen kod Abies *vrsta*

Table 1. Microbes that are inhibited by the products derived from particular *Abies* species

Tabela 1. Mikrobi inhibirani produktima izvedenim iz određenih Abies *vrsta*

BACTERIA			
No.	**Tested microbe**	***Abies* species**	**References**
1.	*Acinetobacter baumannii*	*A. alba*	Broznić *et al.*, 2018
2.	*Acinetobacter bohemicus*	*A. alba*	Garzoli *et al.*, 2021
3.	*Acinetobacter* sp.	*A. numidica*	Tlili Ait Kaki *et al.*, 2012
4.	*Bacillus brevis*	*A. alba* *A. cilicica* *A. nordmanniana* *A. koreana* *A. firma*	Bağci & Diğrak, 1996; Kizil *et al.*, 2002; Dayisoylu *et al.*, 2009
5.	*Bacillus cereus*	*A. alba* *A. cilicica* *A. nordmanniana* *A. numidica* *A. koreana* *A. firma*	Bağci & Diğrak, 1996; Kizil *et al.*, 2002; Dayisoylu *et al.*, 2009; Ramdani *et al.*, 2014; Yavaşer *et al.*, 2015; Garzoli *et al.*, 2021
6.	*Bacillus megatherium*	*A. alba* *A. cilicica* *A. nordmanniana* *A. koreana*	Bağci & Diğrak, 1996; Kizil *et al.*, 2002; Dayisoylu *et al.*, 2009
7.	*Bacillus pumilus*	*A. spectabilis*	Gautam *et al.*, 2022
8.	*Bacillus subtilis*	*A. cilicica* *A. nordmanniana* *A. numidica* *A. koreana* *A. spectabilis* *A. holophylla* *A. firma*	Bağci & Diğrak, 1996; Sakar *et al.*, 1998; Kizil *et al.*, 2002; Lee & Hong, 2009; González, 2015; Erylmaz *et al.*, 2016; Mostefa *et al.*, 2016; Gautam *et al.*, 2022
9.	*Bacillus thurigiensis*	*A. cilicica*	Kizil *et al.*, 2002
10.	*Corynebacterium xerosis*	*A. cilicica*	Dayisoylu *et al.*, 2009
11.	*Enterobacter cloacae*	*A. holophylla*	Lee & Hong, 2009
12.	*Enterobacter aerogenes*	*A. alba* *A. cilicica* *A. koreana* *A. firma* *A. holophylla*	Bağci & Diğrak, 1996; Lee & Hong, 2009
13.	*Enterococcus faecalis*	*A. alba* *A. cilicica* *A. numidica* *A. concolor* *A. spectabilis*	Dayisoylu *et al.*, 2009; Ramdani *et al.*, 2014; Mostefa *et al.*, 2016; Saleh & Al-Mariri, 2016; Wajs-Bonikowska *et al.*, 2017; Salamon *et al.*, 2019; Timothy *et al.*, 2021
14	*Enterococcus faecium*	*A. concolor*	Wajs-Bonikowska *et al.*, 2017

BACTERIA			
No.	**Tested microbe**	***Abies* species**	**References**
15	*Escherichia coli*	*A. alba* *A. cilicica* *A. nordmanniana* *A. numidica* *A. koreana* *A. balsamea* *A. concolor* *A. spectabilis* *A. holophylla*	Sakar *et al.*, 1998; Kizil *et al.*, 2002; Pichette *et al.*, 2006; Jeong *et al.*, 2007; Oh *et al.*, 2007; Vishnoi *et al.*, 2007; Lee & Hong, 2009; Tlili Ait Kaki *et al.*, 2012; Lee *et al.*, 2014; Ramdani *et al.*, 2014; González, 2015; Makwana *et al.*, 2015; Erylmaz *et al.*, 2016; Ododo *et al.*, 2016; Wajs-Bonikowska *et al.*, 2017; Salamon *et al.*, 2019; Truchan *et al.*, 2019; Garzoli *et al.*, 2021; Gautam *et al.*, 2022
16.	*Haemofillus influenzae*	*A. holophylla*	Lee *et al.*, 2014
17.	*Klebsiella pneumoniae*	*A. alba* *A. cilicica* *A. numidica* *A. koreana* *A. concolor* *A. holophylla* *A. firma*	Bağci & Diğrak, 1996; Dayisoylu *et al.*, 2009; Lee & Hong, 2009; Tlili Ait Kaki *et al.*, 2012; Lee *et al.*, 2014; Ramdani *et al.*, 2014; Erylmaz *et al.*, 2016; Saleh & Al-Mariri, 2016; Wajs-Bonikowska *et al.*, 2017; Truchan *et al.*, 2019
18.	*Klebsiella oxytoca*	*A. holophylla*	Lee & Hong, 2009
19.	*Kocuria marina*	*A. alba*	Garzoli *et al.*, 2021
20.	*Listeria inocua*	*A. numidica*	Mostefa *et al.*, 2016
21.	*Listeria monocytogenes*	*A. alba* *A. cilicica* *A. koreana* *A. firma*	Bağci & Diğrak, 1996
22.	*Micrococcus luteus*	*A. cilicica* *A. numidica* *A. spectabilis*	Vishnoi *et al.*, 2007; Dayisoylu *et al.*, 2009; Ramdani *et al.*, 2014; Yavaşer *et al.*, 2015; Mostefa *et al.*, 2016
23.	MRSA	*A. cilicica* *A. numidica* *A. sibirica* *A. koreana* *A. balsamea*	Jeong *et al.*, 2007; Tlili Ait Kaki *et al.*, 2012; Coté *et al.*, 2016; Erylmaz *et al.*, 2016; Truchan *et al.*, 2019
24.	*Mycobacterium smegmatis*	*A. cilicica* *A. nordmanniana*	Sakar *et al.*, 1998; Dayisoylu *et al.*, 2009
25.	*Neisseria meningitidis*	*A. holophylla*	Lee *et al.*, 2014
26.	*Proteus vulgaris*	*A. cilicica*	Saleh & Al-Mariri, 2016
27.	*Pseudomonas aeruginosa*	*A. alba* *A. cilicica* *A. numidica* *A. sibirica* *A. koreana* *A. spectabilis* *A. firma*	Bağci & Diğrak, 1996; Kizil *et al.*, 2002; Jeong *et al.*, 2007; Dayisoylu *et al.*, 2009; Tlili Ait Kaki *et al.*, 2012; González, 2015; Erylmaz *et al.*, 2016; Truchan *et al.*, 2019
28.	*Pseudomonas fluorescens*	*A. alba*	Garzoli *et al.*, 2021

BACTERIA			
No.	**Tested microbe**	***Abies* species**	**References**
29.	*Salmonella enterica*	*A. spectabilis*	Gautam *et al.*, 2022
30.	*Salmonella typhi*	*A. spectabilis*	Vishnoi *et al.*, 2007; Gautam *et al.*, 2022
31.	*Salmonella tipymurium*	*A. nordmanniana*	Sakar *et al.*, 1998
32.	*Sarcina lutea*	*A. nordmanniana;*	Sakar *et al.*, 1998
33.	*Staphylococcus aureus*	*A. alba* *A. cilicica* *A. nordmanianna* *A. numidica* *A. koreana* *A. balsamea* *A. concolor* *A. spectabilis* *A. holophylla* *A. firma*	Bağci & Diğrak, 1996; Sakar *et al.*, 1998; Kizil *et al.*, 2002; Pichette *et al.*, 2006; Jeong *et al.*, 2007;Vishnoi *et al.*, 2007; Dayisoylu *et al.*, 2009; Lee & Hong, 2009; Ramdani *et al.*, 2014; González, 2015;Yavaşer *et al.*, 2015; Coté *et al.*, 2016; Erylmaz *et al.*, 2016; Mostefa *et al.*, 2016; Ododo *et al.*, 2016;Wajs-Bonikowska *et al.*, 2017; Broznić *et al.*, 2018;Ambre *et al.*, 2019; Truchan *et al.*, 2019;Timothy *et al.*, 2021; Gautam *et al.*, 2022
34.	*Staphylococcus epidermidis*	*A. alba* *A. numidica* *A. koreana* *A. spectabilis*	Jeong *et al.*, 2007; Oh *et al.*, 2007;Vishnoi *et al.*, 2007;Tlili Ait Kaki *et al.*, 2012; Ramdani *et al.*, 2014; Broznić *et al.*, 2018
35.	*Staphylococcus haemolyticus*	*A. koreana*	Jeong *et al.*, 2007
36.	*Staphylococcus simulans*	*A. koreana*	Jeong *et al.*, 2007
37.	*Shigella boydii*	*A. spectabilis*	Gautam *et al.*, 2022
38.	*Shigella dysenteriae*	*A. spectabilis*	Vishnoi *et al.*, 2007; Gautam *et al.*, 2022
39.	*Shigella flexneri*	*A. koreana* *A. spectabilis*	Jeong *et al.*, 2007; Gautam *et al.*, 2022
40.	*Shigella soneii*	*A. spectabilis*	Gautam *et al.*, 2022
41.	*Streptococcus mutans*	*A. spectabilis*	Timothy *et al.*, 2021
42.	*Streptococcus pneumoniae*	*A. holophylla*	Lee *et al.*, 2014
43.	*Streptococcus pyogenes*	*A. cilicica* *A. holophylla*	Kizil *et al.*, 2002; Lee *et al.*, 2014
44.	*Vibrio cholerae*	*A. spectabilis*	Vishnoi *et al.*, 2007; Gautam *et al.*, 2022

FUNGI			
No.	**Tested microbe**	***Abies* species**	**References**
1.	*Aspergillus niger*	*A. cilicica* *A. spectabilis*	Vishnoi *et al.*, 2007; Saleh & Al-Mariri, 2016
2.	*Candida albicans*	*A. alba* *A. cilicica* *A. sibirica* *A. nordmanniana* *A. koreana* *A. spectabilis*	Bağci & Diğrak, 1996; Kizil *et al.*, 2002; Oh *et al.*, 2007; Vishnoi *et al.*, 2007; Saleh & Al-Mariri, 2016; Noreikaitė *et al.*, 2017; Salamon *et al.*, 2019; Timothy *et al.*, 2021
3.	*Candida glabrata*	*A. holophylla*	Lee & Hong, 2009
4.	*Candida utilis*	*A. nordmanniana*	Sakar *et al.*, 1998
5.	*Cryptococcus neoformans*	*A. holophylla*	Lee & Hong, 2009
6.	*Kluyveromyces fragilis*	*A. cilicica*	Dayisoylu *et al.*, 2009
7.	*Rhodotorula rubra*	*A. cilicica*	Dayisoylu *et al.*, 2009
8.	*Saccharomyces cerevisiae*	*A. cilicica* *A. nordmanniana* *A. numidica* *A. koreana*	Bağci & Diğrak, 1996; Sakar *et al.*, 1998; Dayisoylu *et al.*, 2009; Ramdani *et al.*, 2014
VIRUSES			
No.	**Tested microbe**	***Abies* species**	**References**
1.	Influenza virus	*A. sibirica* *A. beshanzuensis*	Boldyrev *et al.*, 2000; Safatov *et al.*, 2000; Safatov *et al.*, 2005; Hu *et al.*, 2016
2.	Vaccinia virus	*A. sibirica*	Sokolova *et al.*, 2018

CONCLUSIONS – *Zaključci*

After conducting research, it is established that 13 different species of the genus *Abies* were investigated in terms of antimicrobial potential, namely *Abies alba*, *A. cilicica*, *A. nordmanniana*, *A. numidica*, *A. sibirica*, *A. koreana*, *A. balsamea*, *A. concolor*, *A. spectabilis* (syn. *A. webbiana*), *A. holophylla*, *A. firma*, *A. beshanzuensis*, and *A. cephalonica*. All listed species exhibit antibacterial, antifungal, or antiviral properties, due to their various secondary metabolites. According to the number of published results, the most investigated species is *A. spectabilis* (syn. *A. webbiana*), with eight published studies; followed by *A. alba* with seven studies; *A. cilicica* and *A. sibirica* with six studies; *A. nordmanniana*, *A. numidica*, *A. koreana*, *A. balsamea*, and *A. holophylla* with three studies; *A. concolor* with two studies; and *A. firma*, *A. beshanzuensis*, and *A. cephalonica* with one published research regarding the antimicrobial activity for every species. Overall insight revealed that the most investigated plant product of *Abies* species in terms of antimicrobial activity was essential oil, followed by the analysis of different extracts, resin, honeydew honey, and individual compounds isolated from particular species. The vast number of reviewed studies debate the antibacterial effects of different *Abies* products, including the impact on multidrug-resistant pathogens. Furthermore, antifungal investigations were also detected, as well as studies directed toward the identification of natural antiviral compounds.

Since there are endemic species in the genus *Abies* (Xiang *et al.*, 2018), investigations of bioactive potential should consider that fact, mostly because of the sampling behavior, but also in terms of correct understanding of generated results. This review noticed that some endemic *Abies* species were investigated in terms of antimicrobial potential: *A. koreana* (Korea Peninsula), *A. cephalonica* (Greece), *A. firma* (Japan), *A. numidica* (Algeria), and *A. beshanzuensis* (China). Furthermore, the conservation status of the reviewed species varies from least concern to critically endangered. Thus, the near-threatened *Abies* species that are likely to become endangered in the near future are *A. holophylla*, *A. cilicica*, and *A. spectabilis*; *A. koreana* holds endangered status, and it is characterized by a higher risk of extinction in the wild; while *A. numidica* and *A. beshanzuensis* are considered critically endangered species with the highest risk of extinction in the wild. Due to the presented issues, bioprospecting of novel antimicrobial agents from mentioned species should be rationalized, and due to the already recognized antimicrobial potential, conservational practices and *in vitro* elicitation of desirable chemical compounds should be implemented.

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SAŽETAK

Antimikrobna rezistencija predstavlja jedan od najvećih izazova globalnog zdravlja kod ljudi. Teške infekcije uzrokovane mikroorganizmima razlog su velikog broja smrtnih slučajeva diljem svijeta svake godine. Osim smanjene učinkovitosti, sintetski antimikrobni lijekovi mogu imati i veći broj nuspojava, te ozbiljne toksikološke implikacije. Sve navedeno ilustrira potrebu za pronalaskom novih prirodnih antimikrobnih supstanci. Biljke su oduvijek korištene u svrhe liječenja, a moderna nauka potvrđuje njihov veliki bioaktivni potencijal, koji se najprije odnosi na veliki hemijski diverzitet njihovih sekundarnih metabolita. Ova pregledna studija razmatra dobro poznati četinarski rod *Abies* Mill. (jela) kao potencijalni izvor antimikrobnih spojeva. Studija je pretragom naučnih baza podataka izdvojila i analizirala objavljene podatke o antimikrobnom djelovanju različitih vrsta roda *Abies*. Analiza podataka je pokazala da je ukupno 13 različitih vrsta istraživanog roda izučavano u antimikrobnom smislu (Grafikon 1). Kao najviše istraživana vrsta, prema broju publiciranih naučnih članaka, izdvojila se vrsta *A. spectabilis* (syn. *A. webbiana*). Najčešće testirani produkti *Abies* vrsta su bili eterična ulja i ekstrakti (Slika 1). Najveći broj analiziranih istraživanja je testirao antibakterijske odlike, ali su detektovane i studije o antifungalnom i antivirusnom potencijalu *Abies* vrsta. Najširi spektar antimikrobnog djelovanja uočen je kod vrste *A. cilicica* (Grafikon 2). Detaljan pregled antimikrobnog potencijala *Abies* vrsta je prezentiran u Tabeli 1. Ovaj pregled je uočio da su kao potencijalni izvori antimikrobnih supstanci analizirane i određene endemične vrste jela, uključujući i one koje konzervacijski status opisuje kao kritično ugrožene. U tom smislu, potrebno je implementirati racionalne strategije sakupljanja, kao i optimalnu metodologiju identifikacije i izolacije aktivnih supstanci. Kod ugroženih i endemičnih vrsta sa antimikrobnim potencijalom, ističe se posebna potreba za primjenom različitih metoda konzervacije, s ciljem očuvanja nativnih populacija. S obzirom da ovaj pregled literature potvrđuje veliki antimikrobni potencijal roda *Abies*, buduća istraživanja trebaju biti usmjerena na izolaciju pojedinačnih komponenti, uz poštivanje mjera racionalnog sakupljanja i eventualne implementacije *in vitro* elicitacije željenih supstanci.

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