ŠUMARSKI LIST

HRVATSKO ŠUMARSKO DRUŠTVO

UDC 630*
ISSN 0373–1332

11-12

GODINA CXLIX
Zagreb
2025

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Jela Car iz Begovače (*Abies alba* Mill.) visoka 47,5 m raste na Velebitu preko 5 stoljeća. Više na str. 573.

The 47.5 m tall Tzar fir from Begovača (*Abies alba* Mill.) has been growing on Velebit for over 5 centuries. More on page 573.

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Šumarski list online – Journal of forestry Online
Prijava radova – Manuscript submission

https://www.sumari.hr/sumlist

Izdavač:
HRVATSKO ŠUMARSKO DRUŠTVO

Publisher:
CROATIAN FORESTRY SOCIETY

Suizdavač:
Hrvatska komora inženjera šumarstva i drvne tehnologije

Financijska pomoć Ministarstva znanosti, obrazovanja i mladih

Grafička priprema: Branko Meštrić

Tisak: CBprint – Samobor

Naklada 1660 primjeraka

UDK 630* (05):"54-02"/061.2 ISSN 0373-1332

ŠUMARSKI LIST

Znanstveno-stručno i staleško glasilo Hrvatskoga šumarskog društva
Journal of the Forestry Society of Croatia – Zeitschrift des Kroatischen Forstvereins
– Revue de la Societe forestiere Croate

Znanstveni članci podliježu međunarodnoj recenziji. Recenzenti su doktori šumarskih znanosti u Hrvatskoj i drugim zemljama, prema odluci Uredništva.

Na osnovi mišljenja Ministarstva znanosti, obrazovanja i mladih Republike Hrvatske, „Šumarski list" smatra se znanstvenim časopisom.

Časopis referiraju: Science Citation Index Expanded, CAB Abstracts, Forestry Abstracts, Agricola, Pascal, Geobase, SCOPUS, Portal znanstvenih časopisa Republike Hrvatske (Hrčak) i dr.

Scientific articles are subject to international peer review. Reviewers are doctors of forestry sciences in Croatia and other countries, at the decision of the Editorial Board.

Based on the opinion of the Ministry of Science, Education and Youth of the Republic of Croatia, "Forestry Journal" is classified as a scientific magazine.

Articles are abstracted by or indexed in: Science Citation Index Expanded, CAB Abstracts, Forestry Abstracts, Agricola, Pascal, Ge base, SCOPUS, Portal of scientific journal of Croatia (Hrčak) et al.

SADRŽAJ
CONTENTS

Hrvatsko šumarsko društvo

In memoriam

RIJEČ UREDNIŠTVA

NA KRAJU 2025. GODINE

Logično je bilo u 2025. godini Šumarski list broj 1-2/2025 započeti uvodnikom i naslovnicom o 260 godina hrvatskog šumarstva i podsjetnikom na 23. veljače 1765., rođendan hrvatskog šumarstva. Međutim, tada nismo očekivali da će obilježavanje tako velike obljetnice tijekom godine proteći dosta skromno, pogotovo u odnosu na obilježavanje 250 godina hrvatskog šumarstva kada je 2015. godina bila ispunjena s mnoštvom većih i manjih svečanih i radnih aktivnosti. Nažalost, nekoliko događaja u kojima su akteri s područja šumarstva došli u sukob sa zakonom ili je šumarstvo bilo poligon za političke obračune nisu bili dobra podloga za posvećivanje većem iskazivanju počasti prethodnim generacijama šumara koji su stvarali našu slavnu prošlost.

Uvodnik Šumarskog lista broj 3-4/2025 bio je posvećen šokantnom Pravilniku o dopuni pravilnika o utvrđivanju naknada za šumu i šumsko zemljište resornog ministarstva. Njime je za 99 % umanjena naknada u slučajevima darovanja nekretnina u korist jedinica lokalne i područne (regionalne) samouprave te u korist tijela državne uprave za izdvajanje iz šumskogospodarskog područja Republike Hrvatske. Cjelokupna naknada, koja se sastoji od dijela za šumu (drvnu zalihu), šumsko zemljište i za smanjenje općekorisnih funkcija šuma (OKFŠ), svela se samo na 1 % ukupne naknade. Još se jednom potvrdilo da se svakom izmjenom zakonskih i podzakonskih akata u resoru šuma i šumarstva oni dodatno obezvrjeđuju.

Podsjetnikom kako se uvodnik u proteklih 15 godina čak 16 puta bavio istom temom (ne)učinkovitog korištenja državnih resursa osvrnuli smo se u uvodniku Šumarskog lista broj 5-6/2025. Na to nas je ponukalo pisanje u medijima o većem izvozu drva nego namještaja iz Hrvatske. Nažalost, toliki broj osvrtanja na istu temu samo je pokazatelj da nije bilo pomaka na bolje.

Da su šumarije osnovne organizacijske jedinice šumarstva vjerojatno je poznato i laicima van struke. Međutim, negativna iskustva iz prošlosti u kojima se olako pristupalo reorganizacijama i ukidanju šumarija navela su nas da se toj temi posvetimo u Šumarskom listu broj 7-8/2025.

Uvodnik Šumarskog lista broj 9-10/2025 ukazao je na to kako nema napretka u šumarstvu bez znanosti i bez kulture što je u *Deset sentenci o šumi* 2004. godine napisao akademik Dušan Klepac. Poanta uvodnika bio je osvrt na smanjenje ulaganja u šumarsku znanost. Nedostatak takvih ulaganja negativno će se odraziti na stanje šuma i šumarstva u Hrvatskoj.

Struka s tolikom tradicijom i postojanjem brojnih institucija koje ispunjavaju svoje zadaće od obrazovanja kadrova, znanstveno-istraživačkog rada, operativnog šumarstva do staleškog udruživanja ponosi se brojnim obljetnicama pa vrijedi podsjetiti koje smo još obilježili u godini na isteku: 165 godina osnutka Visokoga gospodarskog i šumarskog učilišta u Križevcima, 130 godina osnutka Instituta za jadranske kulture i melioraciju krša u Splitu, 80 godina osnutka Hrvatskoga šumarskog instituta Jastrebarsko, 65 godina samostalnog Šumarskog fakulteta, 35 godina djelovanja Hrvatskih šuma d.o.o. i 30 godina osnutka Akademije šumarske znanosti.

U 2026. godini možemo najaviti sljedeće obljetnice: 180 godina osnivanja Hrvatskoga šumarskog društva, trećeg najstarijeg šumarskog društva u Europi i 150 godina neprekinutog izlaženja znanstveno-stručnog i staleškog glasila Šumarskog lista. Treba podsjetiti kako se u sljedećoj godini navršava i 20 godina postojanja Hrvatske komore inženjera šumarstva i drvne tehnologije.

Svim članovima HŠD i čitateljima našeg lista želimo sretan Božić te uspješnu novu 2026. godinu.

Uredništvo

EDITORIAL

AT THE END OF 2025

It was logical in 2025 to begin Forestry Journal issue 1–2/2025 with an editorial and cover on the 260th anniversary of Croatian forestry and a reminder of 23 February 1765, the birthday of Croatian forestry. However, we did not expect that the commemoration of such a significant anniversary would turn out to be rather modest throughout the year, especially compared to the celebration of 250 years of Croatian forestry, when the year 2015 was filled with numerous major and minor ceremonial and work activities. Unfortunately, several events in which individuals from the forestry sector violated the law, or in which forestry was used as a battleground for political disputes, did not provide a good foundation for devoting greater recognition to the previous generations of foresters who shaped our distinguished past.

The editorial of Forestry Journal issue 3–4/2025 was dedicated to the shocking amendment to the Regulation on determining compensation for forests and forest land issued by the competent ministry. It reduced the compensation by 99% in cases of donating property to local and regional self-government units and to state administration bodies for the purpose of exclusion from the forest management area of the Republic of Croatia. The entire compensation—consisting of the parts for the forest (timber stock), forest land, and the reduction of forest ecosystem services—was reduced to only 1% of the total amount. Once again, it became evident that each amendment to the legal and subordinate acts in the forestry sector further devalues forests and forestry.

With a reminder that over the past 15 years the editorial had addressed the same topic—the (in)efficient use of state resources—no fewer than 16 times, we revisited this topic in the editorial of Forestry Journal issue 5–6/2025. This was prompted by the media coverage about Croatia exporting more timber than furniture. Unfortunately, so many reflections on this topic prove only that there has been no improvement.

Even people outside the profession most likely know that forest offices are the basic organizational units of forestry. However, negative past experiences, in which reorganizations and the abolition of forest offices were approached too lightly, led us to address this topic in Forestry Journal issue 7–8/2025.

The editorial of Forestry Journal issue 9–10/2025 accentuated that there can be no progress in forestry without science and without culture—an idea expressed by academician Dušan Klepac in his *Ten Sentences on Forests* written in 2004. The point of the editorial was to highlight the reduction in investment in forestry science. The lack of such investment will negatively affect the state of forests and forestry in Croatia.

A profession with such a long tradition and with numerous institutions fulfilling their roles—from educating professionals, scientific research, operational forestry to professional associations—takes pride in many anniversaries. It is therefore worth recalling those we commemorated in 2025: 165 years since the founding of the Royal Agriculture and Forestry College in Križevci, 130 years since the founding of the Institute for Adriatic Crops and Karst Reclamation in Split, 80 years since the founding of the Croatian Forest Research Institute in Jastrebarsko, 65 years of the independent Faculty of Forestry, 35 years of Croatian Forests Ltd., and 30 years since the founding of the Academy of Forestry Sciences.

In 2026 we can announce the following anniversaries: 180 years since the founding of the Croatian Forestry Society, the third oldest forestry society in Europe, and 150 years of uninterrupted publication of its scientific, professional, and guild journal—Forestry Journal. It should also be noted that the upcoming year will mark 20 years of the Croatian Chamber of Forestry and Wood Technology Engineers.

We wish all members of the Croatian Forestry Society and all readers of our journal a Merry Christmas and a successful New Year 2026.

Editorial Board

https://doi.org/10.31298/sl.149.11-12.1

Izvorni znanstveni članci – Original scientific papers
Šumarski list, 11-12 (2025): 503-516

TOČNOST PROCJENE ATRIBUTA POJEDINAČNIH STABALA RUČNIM LASERSKIM SKENIRANJEM U STAROJ SASTOJINI HRASTA LUŽNJAKA

ACCURACY OF TREE ATTRIBUTE ESTIMATES BY PERSONAL LASER SCANNING IN AN OLD PEDUNCULATE OAK FOREST

Ante SELETKOVIĆ[1], Albert SEITZ[2], Andro KOKEZA[2], Matej MATOŠEVIĆ[3], Ivan BALENOVIĆ[2]*

SAŽETAK

U radu je testirana točnost trenutno najsuvremenijeg komercijalnog ručnog laserskog skenera (PLS) pri procjeni prsnog promjera i visine stabala u staroj sastojini hrasta lužnjaka (*Quercus robur* L.). Istraživanje je provedeno na tri primjerne plohe polumjera 20 m s ukupno 40 stabala. Kao referentne vrijednosti korišteni su prsni promjeri izmjereni mjernom vrpcom te visine stabala procijenjene statičkim terestričkim laserskim skeniranjem (TLS). Rezultati su pokazali vrlo visoku točnost PLS procjena za oba analizirana atributa: za prsni promjer srednje odstupanje (MD) iznosilo je 0,62 cm (1,28 %), a korijen srednje kvadratne pogreške (RMSE) 1,04 cm (2,13 %), dok su procjene visine stabala ostvarene s MD = 0,22 m (0,69 %) i RMSE = 0,30 m (0,95 %). U oba slučaja uočen je blagi trend precjenjivanja. Utvrđena visoka podudarnost s referentnim vrijednostima (r = 0,995) potvrđuje gotovo savršeno slaganje između PLS procjena i terenskih izmjera prsnih promjera te PLS i TLS procjena visina stabala. Dobiveni rezultati ukazuju da PLS tehnologija, pruža vrlo točne procjene prsnog promjera i visina stabala te predstavlja iznimno perspektivnu metodu za primjenu u operativnoj inventuri šuma.

KLJUČNE RIJEČI: ručno lasersko skeniranje (PLS), LiDAR, prsni promjer, visina stabala, inventura šuma

UVOD

INTRODUCTION

Za potrebe održivog gospodarenja šumama nužno je raspolagati detaljnim i sveobuhvatnim podacima o šumskim resursima, koji se u pravilu prikupljaju inventurom šuma. U većini zemalja u svijetu podaci inventure šuma prikupljaju se prvenstveno pomoću konvencionalnih terenskih mjerenja provedenih na primjernim površinama (Liang i dr. 2022). U Hrvatskoj je način i intenzitet izmjere propisan Pravilnikom o uređivanju šuma (NN 97/2018, 38/2024). Pojednostavljeno, prsni promjer stabala mjeri se uglavnom na sistematskom uzorku primjernih površina, a propisani intenzitet uzorkovanja ovisi o načinu gospodarenja, uzgojnom obliku te starosti sastojine. Iznimno, u jednodobnim sastojinama visokog uzgojnog oblika određenih dobnih razreda i boniteta u kojima se propisuje etat glavnog prihoda u narednom polurazdoblju provodi se tzv. totalna klupaža, tj. mjere se prsni promjeri svih stabala u sastojini. Za razliku od prsnih promjera, izmjera visina stabala zahtijeva znatno veći utrošak vremena, pa visine stabala predstavljaju najskuplji podatak koji se prikuplja u okviru inventura šuma (Durrieu i dr. 2015). Stoga se visine stabala mjere na značajno manjem uzroku stabala nego prsni promjeri. Na temelju izmjerenih visina, konstruira se visinska krivulja i određuje tarifni niz za određenu grupu sastojina (odsjeka). Pored navedenog, terenske izmjere visina

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pojedinačnih stabala u pravilu imaju značajno nižu točnost u odnosu na mjerenja prsnih promjera (Luoma i dr. 2017). Kod uobičajeno korištenih ultrazvučnih visinomjera (Vertex hipsometara), pogreške u procjeni visine stabala mogu iznositi 1–5 m ili čak i više (Ganz i dr. 2019, Stereńczak i dr. 2019, Wang i dr. 2019), i to ponajprije zbog ograničene vidljivosti vrhova krošanja, osobito u šumskim sastojinama kompleksnije strukture (Liang i dr. 2022). Na točnost terenske procjene visina utječe i niz drugih faktora poput vrste drveća i oblika krošnje, visine i oblika stabla (npr. nagnutost), topografije terena, udaljenosti mjerenja te vještine (preciznost) i iskustva operatera (Larsen i dr. 1987, Korning i Thomsen 1994, Bragg i dr. 2014, Stereńczak i dr. 2019, Jurjević i dr. 2020). Nadalje, Tomplaski i dr. (2014) utvrdili su da pogreške u procjenama visine stabala imaju značajniji utjecaj na procjene volumena stabala nego pogrešna identifikacija vrsta stabala.

Iako su konvencionalne terenske metode inventure šuma provjerene i u određenoj mjeri pouzdane, one su prije svega radno intenzivne, dugotrajne, a samim time i iziskuju značajna novčana sredstva. Stoga su ograničene na malu uzorkovanu površinu i malu vremensku rezoluciju. Metode daljinskih istraživanja imaju potencijal unaprijediti klasične terenske metode, osobito smanjenjem radno intenzivnih i dugotrajnih mjerenja, što je odavno prepoznato u šumarskoj znanosti i praksi (White i dr. 2016). Najznačajniji napredak u istraživanjima primjene daljinskih istraživanja u inventuri šuma dogodio se tijekom proteklih dva-tri desetljeća pojavom i razvojem tehnologije laserskog skeniranja, poznate i kao LiDAR (engl. *Light Detection and Ranging*) (Wang i dr. 2019). Kao posljedica toga, zračno lasersko skeniranje (ALS – engl. *Airborne Laser Scanning*) implementirano je u operativnim inventurama šuma na razini ploha u određenom broju razvijenih zemalja s vremenski učestalijim nacionalnim skeniranjima (Rahlf i dr. 2014., Wang i dr. 2019). Glavno ograničenje ALS tehnologije je nemogućnost dobivanja informacija o pojedinačnim stablima, posebno u kompleksnijem šumskom okruženju. Međutim, konstantan i brz tehnološki napredak u pogledu senzora i razvoja algoritama doveli su do pojave raznih terestričkih sustava laserskog skeniranja. U usporedbi sa zračnim sustavima, terestrički sustavi mogu prikupiti sveobuhvatne i vrlo precizne podatke o pojedinačnim stablima na detaljnoj razini (npr. grane). Trenutačno, statičko terestričko lasersko skeniranje (TLS – engl. *Terrestrial Laser Scanning*) pruža najvišu geometrijsku kvalitetu među svim senzorima i platformama (Liang i dr. 2022), ali ima ograničenu praktičnu primjenu zbog brzine odnosno sporosti prikupljanja podataka. Naime, kako bi se smanjio učinak zaklonjenosti (okluzije) uzrokovan okolnim stablima i grmljem, odnosno kako bi se dobio oblak točaka koji detaljno opisuje svako stablo na plohi, skeniranje ploha potrebno je provesti s više pozicija koristeći tzv. pristup višestrukog skeniranja. Stoga su glavne primjene TLS-a još uvijek povezane s istraživačkim radovima u inventuri šuma, npr. za prikupljanje detaljnih informacija o svojstvima stabala koje nije jednostavno dobiti klasičnim terenskim metodama (Liang i dr. 2018) ili referentnih podataka za validaciju drugih sustava i izvora podataka (Liang i dr. 2016, Wilkes i dr. 2017, Disney i dr. 2019). Primjerice, TLS se najčešće koristi kao referentni podatak pri procjeni visina dubećih stabala budući da je dokazano kako točnije procjenjuje visinu od klasičnih, konvencionalnih terenskih metoda (Calders i dr. 2015, Disney i dr. 2019).

Suvremeni sustavi terestričkog mobilnog laserskog skeniranja predstavljaju učinkovitu alternativu TLS-u jer mogu potpuno ili značajno smanjiti problem okluzije te značajno ubrzati cjelokupni postupak prikupljanja podataka (Balenović i dr. 2021). Napredak u minijaturizaciji senzora tijekom posljednjih desetak godina rezultirao je razvojem laganih i mobilnih ručnih laserskih skenera (PLS – engl. *Personal Laser Scanning*) koje može nositi ili držati jedna osoba. Glavne prednosti komercijalnih ručnih PLS sustava postignute su zamjenom globalnog navigacijskog satelitskog sustava (GNSS-a – engl. *Global Navigation Satellite System*) s algoritmom za istovremenu lokalizaciju i kartiranje (SLAM – engl. *Simultaneous Localization And Mapping*), što čini PLS sustave prikladnim za korištenje u šumskim područjima gdje je GNSS signal često degradiran. Prva značajnija preliminarna PLS istraživanja u inventuri šuma započela su prije 10-ak godina (Ryding i dr. 2015, Bauwens i dr. 2016) pojavom prvih komercijalnih PLS instrumenata. Balenović i dr. (2021) dali su detaljan pregled PLS istraživanja u inventuri šuma provedenih u razdoblju od 2015. do 2020. godine te su istaknuli veliki potencijal PLS tehnologije, ali i određena ograničenja uzrokovana tadašnjim tehničkim mogućnostima instrumenata. Tijekom posljednjih pet godina, razvoj PLS instrumenata u pogledu tehničkih karakteristika (npr. domet, brzina i rezolucija skeniranja, integracija panoramske kamere, itd.) vrlo je intenzivan i dinamičan, što je rezultiralo brojnim istraživanjima o mogućnostima njihove primjene u inventuri šuma (Jurjević i dr. 2020, 2021; Mokroš i dr. 2021; Gollob i dr. 2023; Tupinambá-Simões i dr. 2023; Giannetti i dr. 2024; Guan i dr. 2024a; Henrich i dr. 2024; Kokeza i dr. 2024; Sofia i dr. 2024; Kükenbrink i dr. 2025, itd.). Iako su dosadašnja istraživanja ukazala na velik potencijal primjene PLS-a u inventuri šuma, još uvijek se mogu smatrati preliminarnima jer su uglavnom provedena na malom broju primjernih ploha, u sastojinama specifičnih strukturnih karakteristika i s fokusom na točno određeni atribut stabla.

U kontekstu Hrvatske i njenih glavnih šumskih

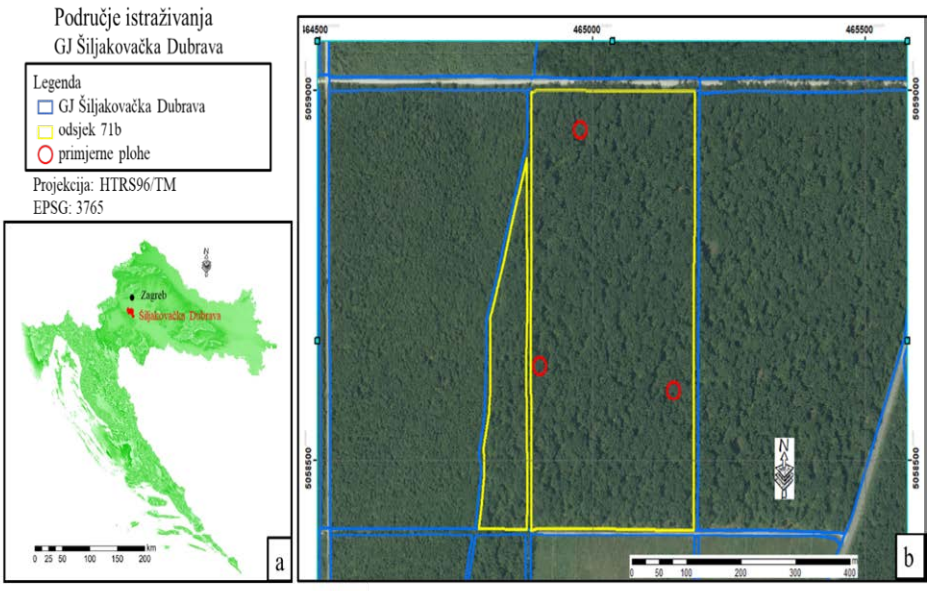
ekosustava provedeno je nekoliko relevantnih istraživanja. Jurjević i dr. (2020) proveli su istraživanje na šest primjernih ploha u nizinskoj, srednjodobnoj šumi hrasta lužnjaka (*Quercus robur* L.) gdje su usporedili različite tehnologije blizu-predmetnih daljinskih istraživanja, i to PLS, lasersko skeniranje iz bespilotne letjelice (ULS – engl. *Unmanned Aerial Scanning*) i aerofotogrametriju iz bespilotne letjelice (UAV_p – engl. *Unmanned Aerial Vehihle Photogrammetry*) te konvencionalne terenske metode za procjenu visine stabala. Istraživanje provedeno u vrijeme mirovanja vegetacije pokazalo je da PLS daje najtočnije procjene visina, osobito za stabla viša od 21 m (dominantna i kodominantna etaža). Na istom području, Jurjević i dr. (2021) evaluirali su točnost različitih blizu-predmetnih tehnologija daljinskih istraživanja (TLS, PLS, ULS, UAV_p) za izradu digitalnog modela reljefa i utvrdili da se korištenjem navedenih tehnologija postiže veća točnost od klasičnih metoda izrade digitalnih modela reljefa (zračno lasersko skeniranje i digitalna aerofotogrametrija iz zrakoplova). Nadalje, Kokeza i dr. (2024) proveli su preliminarno testiranje dva najsuvremenija komercijalna PLS instrumenta (GeoSlam ZEB Horizon, Faro Orbis) na jednoj primjernoj plohi u starijoj nizinskoj šumi hrasta lužnjaka za procjenu prsnog promjera stabala te utvrdili da noviji uređaj s poboljšanim karakteristikama (Faro Orbis) daje rezultate nešto veće točnosti. Također je utvrđeno kako složenije sheme skeniranja dodatno povećavaju preciznost rezultata. Na temelju dosadašnjih spoznaja može se zaključiti da PLS trenutno predstavlja najperspektivniju tehnologiju laserskog skeniranja za primjenu u operativnoj inventuri šuma. Ipak, zbog ograničenog broja provedenih istraživanja još uvijek nedostaju smjernice o najboljoj praksi za prikupljanje i obradu PLS podataka (Balenović i dr. 2021, Liang i dr. 2022). S obzirom na stalan i brz razvoj PLS uređaja i softverskih rješenja, nužno je provoditi kontinuirana i detaljna istraživanja kako bi se unaprijedila njihova primjena u preciznoj inventuri šuma. Glavni cilj ovog istraživanja je testirati točnost tehnologije ručnog laserskog skeniranja korištenjem trenutno najsuvremenijeg komercijalnog PLS instrumenta za procjenu prsnog promjera i visina stabala u staroj sastojini hrasta lužnjaka.

MATERIJAL I METODE

MATERIAL AND METHODS

Područje istraživanja – *Study area*

Istraživanjem su obuhvaćene tri kružne primjerne plohe polumjera 20 m u staroj sastojini (145 godina starosti) uređajnog razreda hrasta lužnjaka (odsjek 71b) u gospodarskoj jedinici Šiljakovačka Dubrava na području Uprave šuma podružnica Zagreb, šumarije Velika Gorica (Slika 1). Inače mješovita sastojina hrasta lužnjaka i običnoga graba (*Carpinus betulus* L.) II boniteta, u vrijeme prikupljanja podataka (ožujak 2025. godine) nalazila se u fazi prirodne obnove oplodnim sječama tijekom koje su već provedeni pripremni i naplodni sijek. Stoga su u sastojini tijekom prikupljanja podataka bila prisutna samo stabla hrasta lužnjaka ostavljena za dovršni sijek. Tri kružne primjerne plohe uključene u ovo istraživanje odabrane su iz većeg uzorka sistematski postavljenih primjernih ploha (100 × 100 m) na temelju broja stabala, s ciljem da predstavljaju strukturne karakteristike čitave sastojine. Odabrane su plohe s 11, 13 i 16 stabala hrasta lužnjaka. Teren na području istraživanja je ravničarski bez nagiba, a nadmorska visina terena kreće se oko 116 metara.



Slika 1. Područje istraživanja: a) lokacija gospodarske jedinice Šiljakovačka Dubrava u Hrvatskoj, b) prostorni raspored primjernih ploha u sastojini (odsjek 71b).
Figure 1 Study area: a) location of the Šiljakovačka Dubrava Management Unit in Croatia, b) spatial distribution of the sample plots in the stand (subcompartment 71b).

Detaljna terenska izmjera – *Detailed field measurements*

Detaljna terenska izmjera na primjernim plohama provedena je u stanju mirovanja vegetacije, početkom ožujka 2025. godine. Prvotno je centar plohe obilježen geodetskom oznakom te mu je pozicija precizno izmjerena GNSS instrumentom Trimble R12i (Trimble Inc., Westminster, Colorado, SAD) povezanim na hrvatski pozicijski sustav (CROPOS – engl. *CROatian POsitioning System*) koristeći visokoprecizni servis pozicioniranja u realnom vremenu (VPPS) s kojim se postiže deklarativna točnost mjerenja od ≈ 2 – 4 cm (Dragčević i dr. 2016). Osim centra plohe, na svakoj plohi su na isti način obilježene i izmjerene pozicije četiri orijentacijske točke pravilno raspoređene na sjevernom, zapadnom, južnom i istočnom rubu plohe. Orijentacijske točke su se naknadno koristile za georeferenciranje TLS i PLS podataka (oblaka točaka). Potom je svakom stablu na plohi izmjerena pozicija, provedena obilježba i numeracija stabala, te izmjeren opseg odnosno prsni promjer. Pozicija svakog stabla dobivena je mjerenjem udaljenosti i azimuta od centra plohe. Za mjerenje udaljenosti korišten je Vertex IV daljinomjer (Haglöf Sweden AB, Långsele, Sweden), a za mjerenje azimuta busola Suunto KB-14 (Suunto Oy, Vantaa, Finland). Stabla su numerirana s pozicije centra plohe gledano prema sjeveru pa u smjeru kazaljke na satu. Na svakom stablu na visini 1,3 m od tla drvomarker sprejom označeno je mjesto izmjere opsega odnosno prsnog promjera. Visina od 1,3 m iznad tla određena je prislanjanjem letve uz samo stablo. Izmjera opsega odnosno prsnog promjera provedena je mjernom vrpcom s milimetarskom podjelom i to na prethodno označenoj visini mjerenja.

Lasersko skeniranje – *Laser scanning*

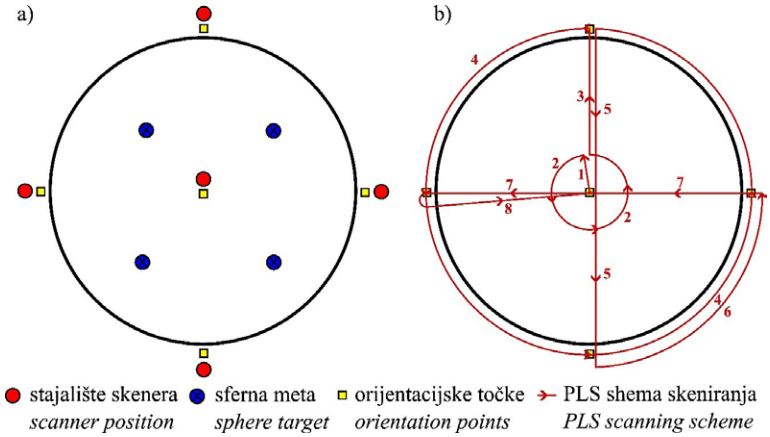
Statičko terestričko lasersko skeniranje (TLS) i mobilno ručno lasersko skeniranje (PLS) provedeno je gotovo istovremeno kada i detaljna terenska izmjera, početkom ožujka 2025. godine. Za prikupljanje TLS podataka korišteni su laserski skener FARO Focus Premium 150 (FARO Technologies Inc., Lake Mary, Florida, USA), predstavljen na tržištu 2022. godine (Slika 2, Tablica 1), te pristup višestrukog skeniranja (Slika 3a). Skeniranje se izvodilo s pet stajališta na svakoj plohi, uključujući centar plohe i četiri stajališta raspoređenih u blizini orijentacijskih točaka udaljenih približno 1 m od granice plohe. Za potrebe naknadne registracije (povezivanja) stajališta odnosno TLS podataka, unutar svake plohe postavljene su četiri sfere raspoređene na način da su najmanje tri bile vidljive sa svakog stajališta skeniranja. Skeniranje je provedeno s postavkama rezolucije ¼ i kvalitete 4x. Rezolucija označava razinu detalja (razlomak ukupne moguće razlučivosti snimanja), dok kvaliteta određuje broj ponavljanja istog mjerenja po točki. Odabrani parametri rezultirali su trajanjem skeniranja od približno pet minuta po stajalištu. Uključujući promjene položaja i podešavanje stajališta, ukupno vrijeme skeniranja jedne plohe iznosilo je oko jedan sat.

Prikupljanje PLS podataka provedeno je laserskim skenerom FARO Orbis (FARO Technologies Inc., Lake Mary, Florida, USA), predstavljenim na tržištu krajem 2023. godine (Slika 2, Tablica 2). Skeniranje se provodilo prema unaprijed definiranom obrascu kretanja kroz plohu. Shema kretanja oblikovana je tako da omogući optimalnu pokrivenost plohe, odnosno da sva stabla budu skenirana iz više smjerova. Operator je skeniranje započeo u centru plohe te se kretao po zadanoj shemi, pritom se zaustavljajući na orijentacijskim točkama radi naknad-

Slika 2. Laserski skeneri korišteni u istraživanju: TLS instrument FARO Focus Premium 150 (lijevo) i PLS instrument FARO Orbis (desno).
Figure 2 Laser scanners used in the research: FARO Focus Premium 150 TLS instrument (left) and FARO Orbis PLS instrument (right).

Tablica 1. Osnovne specifikacije FARO Focus Premium 150 i FARO Orbis instrumenata.
Table 1 The main specifications of FARO Focus Premium 150 and FARO Orbis instruments.

	FARO Focus Premium 150	Faro Orbis
Domet (m) *Range (m)*	0,5 - 150	120
Brzina prikupljanja (točaka/sek) *Acquisition rate (points/sec)*	2.000.000	640.000
Preciznost (mm) *Precision (mm)*	± 1	5
Vidno polje (°) *Field of View (°)*	300/360	360/290

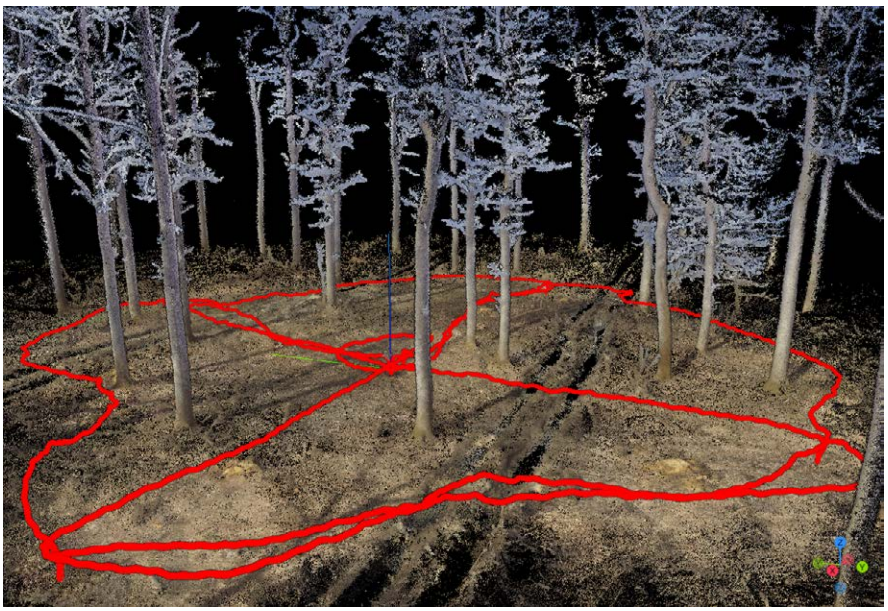


Slika 3. Planirane sheme skeniranja s: (a) FARO Focus Premium 150 i (b) FARO Orbis instrumentima.
Figure 3 Planning scanning schemes with: (a) FARO Focus Premium 150, and (b) FARO Orbis instruments.

nog georeferenciranja podataka. Vrijeme skeniranja svake plohe iznosilo je približno sedam minuta.

Obrada podataka laserskog skeniranja – *Processing of laser scanning data*

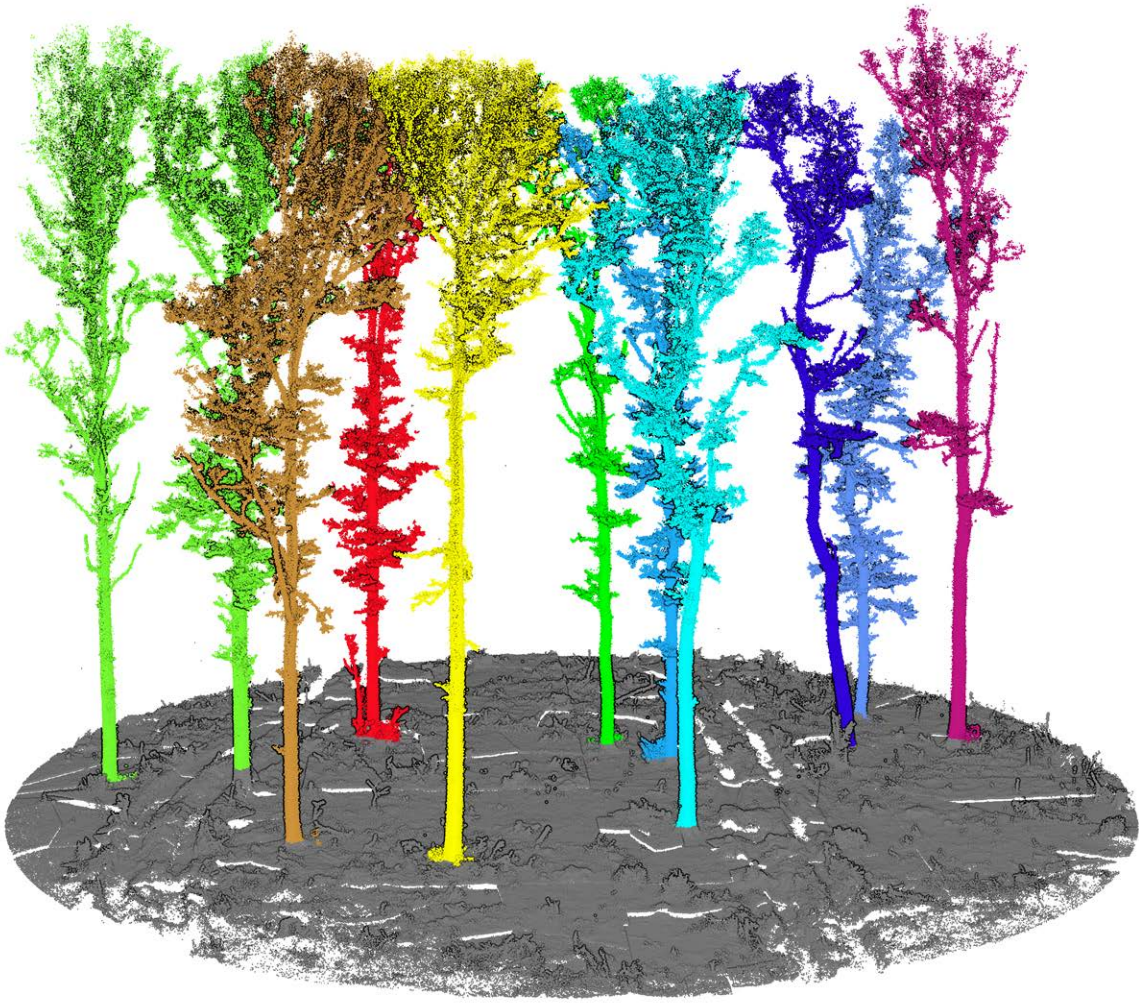
Prije same procjene pojedinačnih atributa stabala, provedena je predobrada prikupljenih TLS i PLS podataka. Predobrada TLS podataka provedena je u softveru FARO SCENE v2025.1.1 (FARO Technologies Inc., Lake Mary, Florida, USA). Prvo je na temelju skeniranih sfera provedena registracija odnosno povezivanje višestrukih skenova (oblaka točaka) jedne plohe u jedan oblak točaka, koji je potom pomoću orijentacijskih točaka georeoferenciran iz lokalnog koordinatnog sustav u HTRS96/TM koordinatni sustav. Georeferencirani oblaci točaka potom su izvezeni u .las format. Za predobradu PLS podataka korišten je softver FARO Connect v2025.1 (FARO Technologies Inc., Lake Mary, Florida, USA) tijekom čega je provedeno georeferenciranje korištenjem orijentacijskih točaka te izvoz oblaka točaka svake plohe u .las formatu (Slika 4).



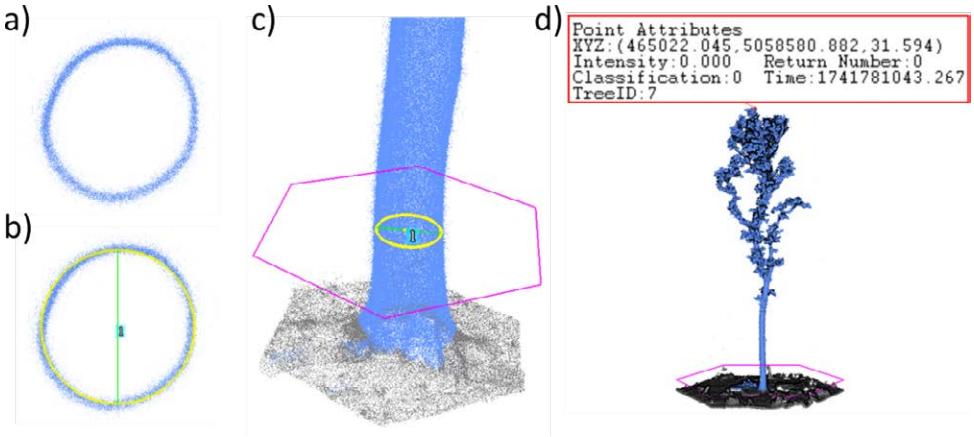
Slika 4. Prikaz georeferenciranog oblaka točaka i provedene sheme skeniranja (crvena linija) u FARO Connect softveru na primjeru jedne plohe.
Figure 4 Georeferenced point cloud with implemented scanning scheme (red line) in FARO Connect for one sample plot.

Obrada TLS i PLS podataka (oblaka točaka) provedena je na identičan način u softveru LiDAR360 v8.1. (GreenValley International, Berkeley, California, SAD). Pri tome je primijenjena polu-automatizirana obrada koja se sastojala od nekoliko koraka. Nakon učitavanja, svaki je oblak točaka obrezan u krug s radijusom od 25 m od centra plohe kako bi se sa sigurnošću zadržale krošnje stabala koja se nalaze uz rub plohe. Na taj je način smanjena veličina oblaka točaka i olakšana daljnja obrada. Potom su iz obrezanih oblaka točaka, korištenjem alata *Remove outliers*, uklonjeni eventualni odstupajući podaci (šumovi). Nakon toga su klasificirane točke tla korištenjem alata *Classify Ground Points*. Na temelju klasificiranih točaka tla, provedena je normalizacija oblaka točaka korištenjem alata *Normalize by Ground Points*. Normalizacijom su apsolutne (nadmorske) visine oblaka točaka transformirane u relativne visine čija nula predstavlja tlo sastojine.

Zatim je slijedila procjena prsnih promjera svih stabala na normaliziranom oblaku točka. U tu svrhu korišten je modul softvera *TLS Seed Point Editor* u kojem je na poprečnom presijeku oblaka točaka na visini od 1,30 m operator prvo manualno označio prsni promjer svakog stabla, a koje je potom precizno aproksimirano kružnicom korištenjem *Fit-by-Circle* algoritma. *Fit-by-Circle* algoritam koristi metodu najmanjih kvadrata za aproksimaciju prsnog promjera iz x, y vrijednosti oblaka točaka. Tako aproksimirani prsni promjeri poslužili su potom kao polazne točke (engl. *Seed Points*) za segmentaciju pojedinačnih stabala iz čitavog oblaka točaka korištenjem algoritma *Point Cloud Segmentation from Seed Points* (Slika 5). Time je osigurano da algoritam segmentira samo stabla povezana s unaprijed određenim polaznim točkama, a ujedno je smanjena mogućnost pogrešaka prilikom segmentacije. U procesu segmentacije, automatski je procijenjena i visina svakog segmentiranog stabla. Automatski procijenjene visine stabala manualno su provjerene i ukoliko je bilo potrebe ispravljene. Pojednostavljeni postupak procjene prsnog promjera i visine stabla iz oblaka točaka prikazan je na Slici 6.



Slika 5. Segmentirani oblak točaka na primjeru jedne plohe.
Figure 5 Segmented point cloud for one sample plot.



Slika 6. Pojednostavljeni postupak procjene atributa pojedinačnih stabala iz oblaka točaka: a) oblak točaka na površini presjeka debla na visini od 1,30 m, b) i c) prsni promjer aproksimiran kružnicom koji je ujedno poslužio kao polazna točka za segmentaciju stabala, d) segmentirano stablo i automatski ili manualno procijenjena visina.
Figure 6 Simplified workflow for estimating individual tree attributes from point clouds: a) point cloud of the stem cross-section at 1.30 m height, b) and c) diameter at breast height approximated by a fitted circle, used as a reference for tree segmentation, d) segmented tree with automatically or manually estimated height.

Ocjena točnosti – *Accuracy assessment*

Kako bi se ocijenila točnost procijenjenih vrijednosti prsnih promjera i visina stabala iz PLS izračunati su srednje odstupanje (MD, prema engl. *mean difference*) te korijen srednje kvadratne pogreške (RMSE, prema engl. *root mean square error*) prema jednadžbama 1 i 2. MD ukazuje na predznak odstupanja procijenjenih vrijednosti, odnosno podcjenjuju li one ili precjenjuju referentne vrijednosti. Za MD se često koristi i termin pristranost (engl. *bias*) jer ukazuje na sistemsku pogrešku procijenjenih vrijednosti. RMSE ukazuje na točnost procijenjenih vrijednosti u odnosu na referentne terenske vrijednosti. MD i RMSE izračunate su u mjernim jedinicama te u postotnom iznosu od referentne vrijednosti prema jednadžbama 3 i 4. Kao referentne vrijednosti za ocjenu točnosti procijenjenih prsnih promjera i visina iz PLS podataka korišteni su prsni promjeri izmjereni mjernom vrpcom u okviru detaljne terenske izmjere, odnosno visine stabala procijenjene iz TLS podataka.

$$MD = \frac{\sum_{i=1}^{n}(\hat{y}_i - y_i)}{n} \quad (1)$$

$$MD_{\%} = \frac{MD}{\bar{y}} \cdot 100 \quad (2)$$

$$RMSE = \sqrt{\frac{\sum_{i=1}^{n}(\hat{y}_i - y_i)^2}{n}} \quad (3)$$

$$RMSE_{\%} = \frac{RMSE}{\bar{y}} \cdot 100 \quad (4)$$

gdje je $\hat{y}_i$ procijenjena vrijednost prsnog promjera ili visine stabla iz PLS podataka za stablo i, y_i je referentna vrijednost prsnog promjera ili visine stabla za stablo i, n je broj stabala na sve tri primjerne plohe, $\bar{y}$ je aritmetička srednja vrijednost referentnog prsnog promjera ili visine stabla.

REZULTATI I RASPRAVA
RESULTS AND DISCUSION

Rezultati ocjene točnosti procijenjenih vrijednosti prsnih promjera i visina stabala iz PLS podataka u odnosu na referentne vrijednosti prikazani su u Tablici 2. Rezultati su objedinjeni za sve tri plohe, odnosno ukupno za 40 stabala hrasta lužnjaka. Prema referentnim podacima, mjernom vrpcom izmjereni su prsni promjeri u rasponu od 33,74 cm do 67,48 cm, sa srednjom vrijednošću od 48,57 cm, dok su iz TLS podataka procijenjene visine stabala u rasponu od 25,44 m do 35,07 m, sa srednjom visinom od 31,48 m. Vrijednosti izmjerenih i procijenjenih prsnih promjera i visina svakog stabla, dobivene terenskim mjerenjima te TLS i PLS podacima, nalaze se u dodatku (Tablica A1).

U odnosu na referentne vrijednosti, odstupanja procijenjenih prsnih promjera iz PLS podataka kretala su se od –0,99 cm do 3,02 cm. Vidljivo je da su minimalna i maksimalna odstupanja te ukupni raspon odstupanja manji od debljinskog stupnja (5 cm). Pri tumačenju rezultata treba uzeti u obzir i način određivanja visine prsnog promjera. U terenskoj izmjeri mjesto mjerenja (1,3 m od tla) određeno je prislanjanjem letve uz deblo, dok je kod PLS podataka promjer automatski procijenjen na visini od 1,3 m nakon klasifikacije i normalizacije oblaka točaka. Drugim riječima, razlike u određivanju visine izmjere mogle su pridonijeti odstupanjima između PLS i referentnih vrijednosti.

Vrlo visoka korelacija (r = 0,995) potvrđuje gotovo

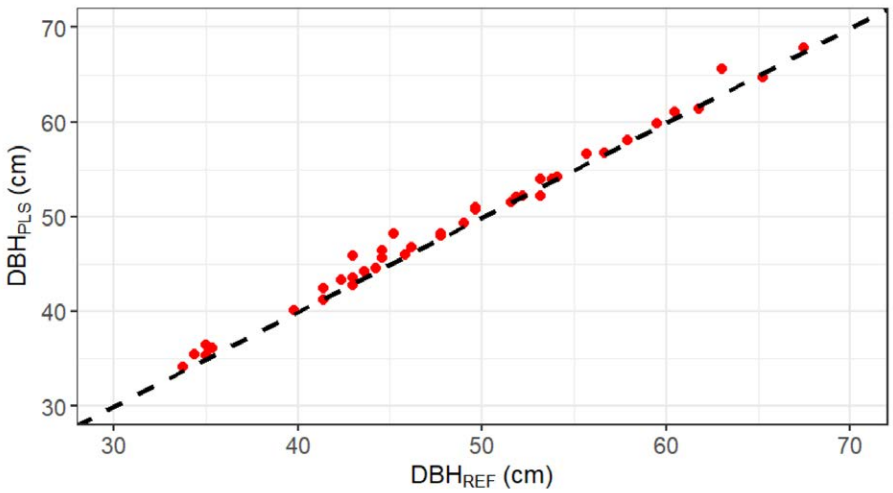
Tablica 2. Točnost prsnih promjera (DBH) i visina stabala (H) procijenjenih iz PLS podataka u odnosu na referentne vrijednosti (prsni promjer izmjeren vrpcom te visina stabala procijenjena iz TLS podataka). Min, Max, SD, MD i RMSE za prsni promjer su iskazane u centimetrima, a za visine u metrima.
Table 2 Accuracy of diameter at breast height (DBH) and tree height (H) estimated from PLS data compared to reference values (DBH measured with a diameter tape and tree height estimated from TLS data). Min, Max, SD, MD and RMSE for DBH are expressed in centimeters, and for H in meters.

Atribut *Attribute*	R	Min	Max	SD	MD	MD%	RMSE	RMSE%
DBH	0,995	-0,99	3,02	0,84	0,62	1,28	1,04	2,13
H	0,995	-0,13	0,92	0,21	0,22	0,69	0,30	0,95

savršenu podudarnost između PLS procijenjenih i terenski izmjerenih prsnih promjera. Prema srednjoj pogrešci (MD = 0,62 cm; $MD_{\%}$ = 1,28 %) utvrđen je blagi trend precjenjivanja PLS procijenjenih prsnih promjera. To potvrđuje i grafički prikaz (Slika 7), na kojem je vidljivo gotovo konstantno blago precjenjivanje PLS procjena u odnosu na referentne vrijednosti, dok se tek manji broj slučajeva nalazi ispod 1:1 linije. Isti trend precjenjivanja zabilježen je i u drugim istraživanjima u lužnjakovim sastojinama korištenjem istog PLS instrumenta (FARO Orbis) (Kokeza i dr. 2024, 2025). Primjerice, Kokeza i dr. (2024) u starijoj lužnjakovoj sastojini (100 godina) testirali su dva najsuvremenija PLS instrumenta (GeoSlam ZEB Horizon i FARO Orbis) te različite sheme skeniranja. Najtočniji rezultati ($MD_{\%}$ = 0,58 %; $RMSE_{\%}$ = 1,42 %) postignuti su upravo FARO Orbisom uz istu shemu skeniranja kao u ovom istraživanju. Nadalje, u istom sastojinskom tipu, ali na drugoj plohi, Kokeza i dr. (2025) istražili su utjecaj razdoblja prikupljanja PLS podataka. Očekivano, nešto bolji rezultati postignuti su u razdoblju mirovanja vegetacije ($MD_{\%}$ = 1,23 %; $RMSE_{\%}$ = 1,76 %) nego u vegetacijskom razdoblju ($MD_{\%}$ = 1,43 %; $RMSE_{\%}$ = 2,04 %). Sveukupno, u ovom istraživanju utvrđen je isti trend precjenjivanja, uz nešto manju točnost u odnosu na prethodno navedena istraživanja. Glavni razlog vjerojatno leži u starosti i strukturi sastojine – manjoj gustoći stabala i većim dimenzijama prsnih promjera nego u starijim sastojinama. Kod stabala hrasta lužnjaka većih dimenzija moguće je precjenjivanje upravo zbog debele i hrapave kore. Na starijim stablima razvijaju se duboke brazde i zadebljanja, pa laserske zrake primarno registriraju „vrhove" kore umjesto prosječne linije debla, što rezultira većim procijenjenim promjerom. Takav je utjecaj potvrđen i u istraživanju Kokeze i dr. (2025), gdje je u bukovoj sastojini zabilježeno manje precjenjivanje ($MD_{\%}$ = 0,90 %) nego u lužnjakovoj ($MD_{\%}$ = 1,43 %). Ipak, zahvaljujući boljoj kvaliteti instrumenta i terenskim uvjetima, u lužnjakovoj je sastojini postignuta nešto veća točnost ($RMSE_{\%}$ = 2,04 %) nego u bukovoj ($RMSE_{\%}$ = 2,13 %).

Općenito, dobiveni rezultati u skladu su s nalazima drugih istraživanja (npr. Gollob i dr. 2020, Hyyppä i dr. 2020, Mokroš i dr. 2021, Guan i dr. 2024a, Kokeza i dr. 2024, Sofia i dr. 2024, Hrdina i dr. 2025, Kokeza i dr. 2025, Kükenbrink i dr. 2025). U njima su korišteni instrumenti poboljšanih karakteristika (npr. ZEB Horizon, FARO Orbis), a procjene prsnog promjera ostvarene su s pogreškama ($RMSE_{\%}$) u rasponu od 2,04 % do 25,92 %. Međutim, uz izuzetak domaćih istraživanja (Kokeza i dr. 2024, 2025), izravna usporedba nije moguća zbog razlika u strukturi sastojina, metodama prikupljanja podataka (npr. veličina i oblik plohe, shema skeniranja) te postupcima obrade (npr. softveri, algoritmi).

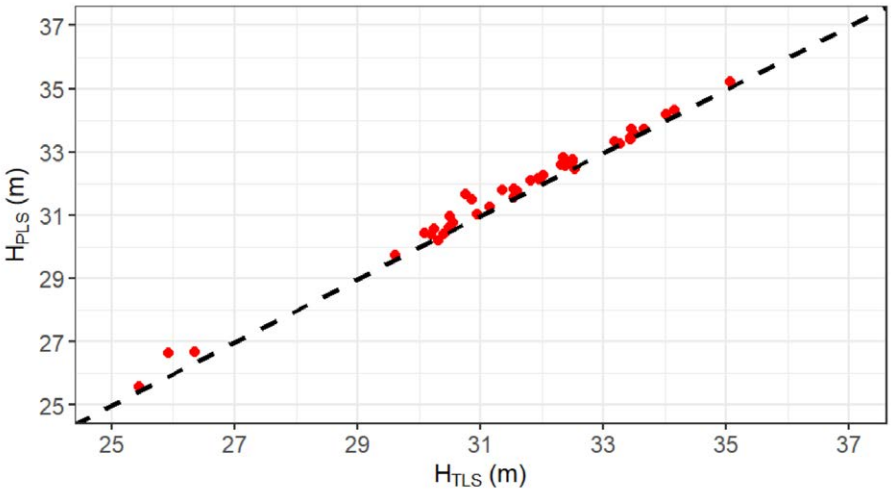
U odnosu na referentne vrijednosti visina stabala procijenjenih TLS-om, iz PLS podataka zabilježena su



Slika 7. Usporedba prsnih promjera procijenjenih iz PLS podataka (DBH_{PLS}) i referentnih prsnih promjera izmjerenih mjernom vrpcom (DBH_{REF}).
Figure 7 Comparison of diameters at breast height estimated from PLS data (DBH_{PLS}) and reference diameters at breast height measured with a diameter tape (DBH_{REF})..

minimalna odstupanja u rasponu od –0,13 m do 0,92 m (Tablica 2). Vrlo visoka korelacija (r = 0,995) potvrđuje gotovo savršenu podudarnost između visina stabala procijenjenih TLS-om i PLS-om. Dobro slaganje između dvaju izvora podataka dodatno potvrđuju mjere točnosti. Prema srednjoj pogrešci (MD = 0,22 m; $MD_{\%}$ = 0,69 %), uočen je blagi trend precjenjivanja visina stabala procijenjenih iz PLS podataka u odnosu na TLS. Navedeni obrazac vidljiv je i na grafičkom prikazu (Slika 8), gdje su visine tek triju stabala neznatno podcijenjene, dok su kod preostalih 37 stabala uglavnom blago precijenjene, tj. smještene neposredno iznad linije 1:1 grafikona. Nadalje, dobivena vrijednost RMSE od 0,30 m (0,95 %) također potvrđuje minimalna odstupanja i visoku točnost PLS procjena visina stabala u odnosu na referentne TLS vrijednosti.

Ranija istraživanja (Cabo i dr. 2018, Giannetti i dr. 2018)



Slika 8. Usporedba visina stabala procijenjenih iz PLS podataka (H_{PLS}) i referentnih visina procijenjenih iz TLS podataka (H_{TLS}).
Figure 8 Comparison of tree heights estimated from PLS data (H_{PLS}) and reference tree heights estimated from TLS data (H_{TLS}).

pokazala su slabiju točnost procjene visina stabala, ponajprije zbog ograničenog dometa senzora. Primjerice, Cabo i dr. (2018) u urbanoj park-šumi (maksimalne visine stabala 18 m) procijenili su visine s RMSE od 1,34 m, dok su u planinskoj borovoj šumi (maksimalne visine 33 m) dobili RMSE od 9,44 m. Giannetti i dr. (2018) u mediteranskoj mješovitoj sastojini, unatoč nižim maksimalnim visinama (19 m), utvrdili su značajno podcjenjivanje i odstupanje procjena (MD = –4,61 m; RMSE = 2,15 m). U tim istraživanjima korišteni su PLS instrumenti (ZEB-REVO i ZEB1) čiji maksimalni domet skeniranja u šumama iznosi svega 15 – 20 m (Balenović i dr. 2021), što dovodi do izraženog podcjenjivanja stabala viših od 15 m.

Razvojem tehnologije značajno se povećao domet senzora. Od 2019. godine dostupni su instrumenti poput ZEB Horizona (100 m), a od 2023. i instrumenti poput FARO Orbisa (120 m). Istraživanja provedena novijom generacijom PLS instrumenata (Jurjević i dr. 2020, Hyypä i dr. 2020, Vandendaele i dr. 2022, Kokeza i dr. 2025) pokazala su znatno bolju točnost. Tako su Jurjević i dr. (2020) u srednjodobnim lužnjakovim sastojinama, usporedbom PLS (ZEB Horizon) i terenskih mjerenja, utvrdili MD od 0,45 m (1,82 %) i RMSE od 1,11 m (4,45 %). Hyypä i dr. (2020) u borealnim mješovitim sastojinama, koristeći ULS kao referencu, dobili su u rjeđim sastojinama MD od 1,3 m (6,0 %) i RMSE od 1,8 m (8,7 %), a u gušćim sastojinama MD od 0,68 m (3,0 %) i RMSE od 1,1 m (4,9 %). Vandendaele i dr. (2022) su u kanadskim mješovitim bjelogoričnim sastojinama, primjenom instrumenta Hovermap (100 m dometa) i usporedbom s TLS podacima, postigli RMSE od 0,42 m (1,78 %).

U ovom istraživanju postignuti su još točniji rezultati (Tablica 2; $MD_{\%}$ = 0,69 %; $RMSE_{\%}$ = 0,95 %). Razlozi mogu biti višestruki: poboljšane tehničke značajke FARO Orbisa u odnosu na ZEB Horizon i Hovermap, shema skeniranja i metode obrade podataka, struktura sastojine, kao i pouzdanost referentnih podataka. Direktna usporedba moguća je tek s istraživanjem Kokeze i dr. (2025), provedenim u starijoj lužnjakovoj sastojini korištenjem istog instrumenta, identične sheme skeniranja i obrade te evaluacije na temelju TLS podataka. U tom su istraživanju autori dobili vrlo slične rezultate, iako nešto niže točnosti (MD = 0,33 m; 1,23 %; RMSE = 0,47 m; 1,76 %), što se može pripisati razlikama u strukturi sastojina, odnosno većoj gustoći stabala na primjernim plohama koja otežava vidljivost vrhova krošnji. Zajedničko ovom i svim prethodno navedenim istraživanjima (Jurjević i dr. 2020, Hyypä i dr. 2020, Vandendaele i dr. 2022, Kokeza i dr. 2025) jest tendencija blagog precjenjivanja visina stabala procijenjenih PLS-om, neovisno o vrsti i tipu korištenih referentnih podataka. S obzirom na to, moguće je pretpostaviti da PLS daje možda i najtočnije procjene visina stabala u odnosu na metode

koje su u ranijim istraživanjima korištene kao referentne (TLS, ULS) ili za usporedbu (klasične terenske metode). Naime, već je u uvodnom poglavlju spomenuto da pogreška procjene visine stabala klasičnim terenskim metodama (ultrazvučni visinomjeri) može iznositi 1 – 5 m ili više (Ganz i dr. 2019, Stereńczak i dr. 2019, Wang i dr. 2019). Vandendaele i dr. (2022) već su raspravljali kako PLS može davati točnije procjene visina stabala nego TLS jer je TLS statički sustav i stoga pod većim utjecajem zaklanjanja (okluzije). Nadalje, brojna istraživanja (npr. Li i dr. 2023, Guan i dr. 2024b, Mîzgaciu i dr. 2025, Tupinambá-Simões i dr. 2025) potvrdila su da ULS podaci pokazuju tendenciju podcjenjivanja visina stabala zbog zaklonjenosti vrhova krošnji, manje gustoće točaka na vrhovima stabala i filtriranja izoliranih točaka tijekom obrade. Ipak, da bi se sa sigurnošću moglo potvrditi da PLS daje najtočnije procjene visina stabala, potrebno je provesti dodatna istraživanja izravne usporedbe različitih metoda, uz pouzdane referentne podatke (npr. izmjera dužina oborenih stabala predviđenih za sječu tijekom prorjeda ili oplodnih sječa).

ZAKLJUČCI
CONCLUSIONS

U ovom istraživanju testirana je točnost ručnog laserskog skeniranja (PLS) korištenjem trenutno najsuvremenijeg komercijalnog instrumenta za procjenu prsnog promjera i visina stabala u staroj sastojini hrasta lužnjaka. Procjene dobivene iz PLS podataka uspoređene su s referentnim vrijednostima prsnih promjera izmjerenih terenski mjernom vrpcom, odnosno visina stabala procijenjenih iz TLS podataka.

Dobiveni rezultati pokazali su vrlo visoku točnost PLS procjena za oba analizirana atributa stabala. Procjene prsnog promjera ostvarene su s prosječnim odstupanjem (MD) od 0,62 cm (1,28 %) i RMSE od 1,04 cm (2,13 %), uz tendenciju blagog precjenjivanja. Procjene visina stabala pokazale su još veću točnost, s prosječnim odstupanjem (MD) od 0,22 m (0,69 %) i RMSE od 0,30 m (0,95 %), također uz blagi trend precjenjivanja. Utvrđena visoka podudarnost s referentnim vrijednostima (r = 0,995) potvrđuje gotovo savršenu slaganje između PLS procjena i terenskih izmjera prsnih promjera te PLS i TLS procjena visina stabala. Rezultati su u skladu s ranijim istraživanjima koja ukazuju na blago precjenjivanje prsnih promjera i visina pri primjeni PLS tehnologije, ali uz vrlo visoku točnost procjena. Mogući uzroci odstupanja uočeni u ovom istraživanju povezani su sa strukturom sastojine i morfološkim značajkama stabala, osobito debljom i hrapavom korom starijih stabala lužnjaka.

Na temelju provedenog istraživanja može se zaključiti da PLS tehnologija pruža vrlo točne procjene prsnog promjera i visina stabala te predstavlja iznimno perspektivnu metodu za primjenu u operativnoj inventuri šuma. Unatoč tome, nužna su daljnja istraživanja u različitim tipovima šuma i sastojinskim uvjetima radi definiranja smjernica najbolje prakse i veće integracije PLS tehnologije u operativne inventure šuma.

ZAHVALA
ACKNOWLEDGMENT

Ovaj rad sufinancirala je Hrvatska zaklada za znanost projektom HRZZ-IP-2022-10-9246 (Blizu-predmetna daljinska istraživanja za preciznu inventuru šuma; CLOSER-FORINVENT) te dijelom kroz Program znanstveno-istraživačkog rada (ZIR) Hrvatskih šuma d.o.o. projektom „Primjena terestričkog laserskog skeniranja u preciznoj operativnoj izmjeri šuma (LASSCAN-2)".

LITERATURA
REFERENCES

- Balenović, I., X. Liang, L. Jurjević, J. Hyyppä, A. Seletković, A. Kukko, 2021: Hand-held personal laser scaning – Current status and perspectives for forest inventory application. Croatian Journal of Forest Engineering 42 (1): 165–183. https://doi.org/10.5552/crojfe.2021.858
- Balenović, I., A. Kokeza, K. Indir, D. Kuric, F. Domazetović, I. Marić, L. Jurjević, 2024: Prva godina projekta „Primjena terestičkog laserskog skeniranja u preciznoj operativnoj izmjeri šuma". Radovi 49 (1): 1–10. https://hrcak.srce.hr/324565
- Bauwens, S., H. Bartholomeus, K. Calders, P. Lejeune, 2016: Forest inventory with terrestrial LiDAR: A comparison of static and hand-held mobile laser scanning. Forests 7 (6): 127. https://doi.org/10.3390/f7060127
- Bragg, D.C., 2014: Accurately measuring the height of (real) forest trees. Journal of Forestry 112 (1): 51–54. https://doi.org/10.5849/JOF.13-065
- Cabo, C., S. Del Pozo, P. Rodríguez-Gonzálvez, C. Ordóñez, D. González-Aguilera, 2018: Comparing terrestrial laser scanning (TLS) and wearable laser scanning (WLS) for individual tree modeling at plot level. Remote Sensing 10 (4): 540. https://doi.org/10.3390/rs10040540
- Calders, K., G. Newnham, A. Burt, S. Murphy, P. Raumonen, M. Herold, D. Culvenor, V. Avitabile, M. Disney, J. Armston, M. Kaasalainen, 2015: Nondestructive estimates of above-ground biomass using terrestrial laser scanning. Methods in Ecology and Evolution 6 (2): 198–208. https://doi.org/10.1111/2041-210X.12301
- Disney, M., A. Burt, K. Calders, C. Schaaf, A. Stovall, 2019: Innovations in ground and airborne technologies as reference and for training and validation: Terrestrial laser scanning (TLS). Surveys in Geophysics 40: 937–958. https://doi.org/10.1007/s10712-019-09527-x
- Dragčević, D., M. Pavasović, T. Bašić, 2016: Pouzdanost službenih rješenja geoida Republike Hrvatske na području Grada Zagreba. Geofizika 33 (2): 183–206. https://doi.org/10.15233/gfz.2016.33.9
- Durrieu, S., C. Vega, M. Bouvier, F. Gosselin, J.-P. Renaud, L. Saint-André, 2015: Optical remote sensing of tree and stand heights. U (Thenkabail, P.S., ur.): Land Resources Monitoring, Modeling, and Mapping with Remote Sensing. CRC Press, Boca Raton, Florida, pp. 1–30. https://doi.org/10.1201/b19322

- Ganz, S., Y. Käber, P. Adler, 2019: Measuring tree height with remote sensing – A comparison of photogrammetric and LiDAR data with different field measurements. Forests 10 (8): 694. https://doi.org/10.3390/f10080694
- Giannetti, F., L. Passarino, G. Aleandri, C. Borghi, E. Vangi, S. Anzilotti, S. Raddi, G. Chirici, D. Travaglini, A. Maltoni, B. Mariotti, A. Bravo-Oviedo, Y. Giambastiani, P. Rossi, G. D'Amico, 2024: Efficiency of mobile laser scanning for digital marteloscopes for conifer forests in the Mediterranean Region. Forests 15 (12): 2202. https://doi.org/10.3390/f15122202
- Gollob, C., T. Ritter, A. Nothdurft, 2020: Forest inventory with long range and high-speed personal laser scanning (PLS) and simultaneous localization and mapping (SLAM) Ttechnology. Remote Sensing 12 (9): 1509. https://doi.org/10.3390/rs12091509
- Gollob, C., R. Krassnitzer, T. Ritter, A. Tockner, G. Erber, M. Kühmaier, F. Hönigsberger, T. Varch, A. Holzinger, K. Stampfer. A. Nothdurft, 2023: Measurement of individual tree parameters with carriage-based laser scanning in cable yarding operations. Croatian Journal of Forest Engineering 44 (2): 401–417. https://doi.org/10.5552/crojfe.2023.2252
- Guan, T., Y. Shen, Y. Wang, P. Zhang, R. Wang, F. Yan, 2024a: Advancing forest plot surveys: A comparative study of visual vs. LiDAR SLAM technologies. Forests 15: 2083. https://doi.org/10.3390/f15122083
- Guan, H., W. Li, Q. Wang, Y. Xu, 2024b: Evaluating UAV LiDAR for tree height and crown detection in temperate forests. Remote Sensing of Environment 302: 113–129. https://doi.org/10.1016/j.rse.2023.113129
- Henrich, J., J. van Delden, D. Seidel, T. Kneib, A.S. Ecker, 2024: TreeLearn: A deep learning method for segmenting individual trees from ground-based LiDAR forest point clouds. Ecological Informatics 84: 102888. https://doi.org/10.1016/j.ecoinf.2024.102888
- Hrdina, M., J.A. Molina-Valero, K. Kuželka, S. Tatsumi, K. Yamaguchi, Z. Melichová, M. Mokroš, P. Surový, 2025: Obtaining the highest quality from a low-cost mobile scanner: A comparison of several pipelines with a new scanning device. Remote Sensing 17 (15): 2564. https://doi.org/10.3390/rs17152564
- Hyyppa¨, E., X. Yu, H. Kaartinen, T. Hakala, A. Kukko, M. Vastaranta, J. Hyyppa¨, 2020: Comparison of backpack, handheld, under-canopy UAV, and above-canopy UAV laser scanning for field reference data collection in boreal forests. Remote Sensing 12: 3327. https://doi.org/10.3390/rs12203327
- Jurjević, L., X. Liang, M. Gašparović, I. Balenović, 2020: Is field-measured tree height as reliable as believed – Part II, A comparison study of tree height estimates from conventional field measurement and low-cost close-range remote sensing in a deciduous forest. ISPRS Journal of Photogrammetry and Remote Sensing 169: 227–241. https://doi.org/10.1016/j.isprsjprs.2020.09.014
- Jurjević, L., M. Gašparović, X. Liang, I. Balenović, 2021: Assessment of close-range remote sensing methods for DTM estimation in a lowland deciduous forest. Remote Sensing 13 (11): 2063. https://doi.org/10.3390/rs13112063
- Kokeza, A., L. Jurjević, F. Domazetović, I. Marić, A. Šiljeg, D. Medak, K. Indir, D. Kuric, I. Balenović, 2024: Testing the performance of hand-held personal laser scanning systems for precision forest inventory. U (Gašparović, M., ur.): Proceedings of the International Conference of Environmental Remote Sensing and GIS (ICERS), Zagreb, Croatia, July 11–12, 2024, pp. 117–120. https://doi.org/10.5281/zenodo.11657299
- Kokeza, A., D. Medak, F. Domazetović, I. Marić, A. Šiljeg, A. Seitz, I. Balenović, 2025: Influence of vegetation period on personal laser scanning accuracy for tree attribute estimation in pedunculate oak and European beech forests. The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences (u tisku).
- Korning, J., K. Thomsen, 1994: A new method for measuring tree height in tropical rain forest. Journal of Vegetation Science 5 (1): 139–140. https://doi.org/10.2307/3235647
- Kükenbrink, D., M. Marty, N. Rehush, M. Abegg, C. Ginzler, 2025: Evaluating the potential of handheld mobile laser scanning for an operational inclusion in a national forest inventory – A Swiss case study. Remote Sensing of Environment 321: 114685. https://doi.org/10.1016/j.rse.2025.114685
- Larsen, D.R., D.W. Hann, S.C. Stearns-Smith, 1987: Accuracy and precision of the tangent method of measuring tree height. Western Journal of Applied Forestry 2 (1): 26–28. https://doi.org/10.1093/wjaf/2.1.26
- Li, Z., S. Chen, X. Liang, 2023: Performance of UAV-based LiDAR in estimating forest structural attributes compared with TLS. ISPRS Journal of Photogrammetry and Remote Sensing 196: 45–59. https://doi.org/10.1016/j.isprsjprs.2023.01.002
- Liang, X., V. Kankare, J. Hyyppä, Y. Wang, A. Kukko, H. Haggrén, X. Yu, H. Kaartinen, A. Jaakkola, F. Guan, M. Holopainen, 2016: Terrestrial laser scanning in forest inventories. ISPRS Journal of Photogrammetry and Remote Sensing 115: 63–77. https://doi.org/10.1016/j.isprsjprs.2016.01.006
- Liang, X., J. Hyyppä, H. Kaartinen, M. Lehtomäki, J. Pyörälä, N. Pfeifer, M. Holopainen, G. Brolly, P. Francesco, J. Hackenberg, H. Huang, H.W. Jo, M. Katoh, L. Liu, M. Mokroš, J. Morel, K. Olofsson, J. Poveda-Lopez, J. Trochta, D. Wang, J. Wang, Z. Xi, B. Yang, G. Zheng, V. Kankare, V. Luoma, X. Yu, L. Chen, M. Vastaranta, N. Saarinen, Y. Wang, 2018: International benchmarking of terrestrial laser scanning approaches for forest inventories. ISPRS Journal of Photogrammetry and Remote Sensing 144: 137–179. https://doi.org/10.1016/j.isprsjprs.2018.06.021
- Liang, X., A. Kukko, I. Balenović, N. Saarinen, S. Junttila, V. Kankare, M. Holopainen, M. Mokroš, et al., 2022: Close-range remote sensing of forests: The state of the art, challenges, and opportunities for systems and data acquisitions. IEEE Geoscience and Remote Sensing Magazine 10 (3): 32–71. https://doi.org/10.1109/MGRS.2022.3168135
- Luoma, V., N. Saarinen, M.A. Wulder, J.C. White, M. Vastaranta, M. Holopainen, J. Hyyppä, 2017: Assessing precision in conventional field measurements of individual tree attributes. Forests 8 (2): 38.
- Mîzgaciu, D., A. Ganne, S. Legros, S. Mermoz, A. Bouvet, T. Le Toan, 2025: A comparative analysis of UAV LiDAR and mobile laser scanning for tree height and canopy structure estimation. Forests 16 (9): 1481. https://doi.org/10.3390/f16091481
- Mokroš, M., T. Mikita, A. Singh, J. Tomaštík, J. Chudá, P. Wężyk, K. Kuželka, P. Surový, M. Klimánek, K. Zięba-Kulawik, R. Bobrowski, X. Liang, 2021: Novel low-cost mobile mapping systems for forest inventories as terrestrial laser scanning alternatives. International Journal of Applied Earth Observation and Geoinformation 104: 102512. https://doi.org/10.1016/j.jag.2021.102512
- Rahlf, J., J. Breidenbach, S. Solberg, E. Næsset, R. Astrup, 2014: Comparison of four types of 3D data for timber volume estimation. Remote Sensing of Environment 155: 325–333. https://doi.org/10.1016/j.rse.2014.08.036
- Ryding, J., E. Williams, M.J. Smith, M.P. Eichhorn, 2015: Assessing handheld mobile laser scanners for forest surveys. Remote Sensing 7 (1): 1095–1111. https://doi.org/10.3390/rs70101095
- Sofia, S., F. Giannetti, S. Buscarini, G. Chirici, C. Serena, F. Maetzke, M. Miozzo, D. Travaglini, D.S. La Mela Veca, 2024: View of comparing efficiency, timing and costs of different walking paths in HMLS LIDAR survey. Annals of Forest Research 67: 87–107. https://doi.org/10.15287/afr.2024.3671
- Stereńczak, K., M. Mielcarek, B. Wertz, K. Bronisz, G. Zajączkowski, A.M. Jagodziński, W. Ochał, M. Skorupski, 2019: Factors influencing the accuracy of ground-based tree-height measurements for major European tree species. Journal

of Environmental Management 231: 1284–1292. https://doi.org/10.1016/j.jenvman.2018.09.100.

- Tompalski, P., N.C. Coops, J.C. White, M.A. Wulder, 2014: Simulating the impacts of error in species and height upon tree volume derived from airborne laser scanning data. Forest Ecology and Management 327: 167–177. https://doi.org/10.1016/j.foreco.2014.05.011
- Tupinambá-Simões, F., A. Pascual, J. Guerra-Hernández, C. Ordóñez, T. de Conto, F. Bravo, 2023: Assessing the performance of a handheld laser scanning system for individual tree mapping – A mixed forests showcase in Spain. Remote Sensing 15 (5): 1169. https://doi.org/10.3390/rs15051169
- Tupinambá-Simões, F., S. Saatchi, R. Dubayah, M.L. Clark, K. Calders, C.A. Silva, 2025: Combining hand-held and drone-based LiDAR for forest carbon monitoring. European Journal of Forest Research 144 (2): 345–362. https://doi.org/10.1007/s10342-025-01772-7
- Vandendaele, B., O. Martin-Ducup, R.A. Fournier, G. Pelletier, P. Lejeune, 2022: Mobile laser scanning for estimating tree structural attributes in a temperate hardwood forest. Remote Sensing 14 (18): 4522. https://doi.org/10.3390/rs14184522
- Wang, Y., M. Lehtomäki, X. Liang, J. Pyörälä, A. Kukko, A. Jaakkola, J. Liu, Z. Feng, R. Chen R, J. Hyyppä, 2019: Is field-measured tree height as reliable as believed – A comparison study of tree height estimates from field measurement, airborne laser scanning and terrestrial laser scanning in a boreal forest. ISPRS Journal of Photogrammetry and Remote Sensing 147: 132–145. https://doi.org/10.1016/j.isprsjprs.2018.11.008
- White, J.C., N.C. Coops, M.A. Wulder, M. Vastaranta, T. Hilker, P. Tompalski, 2016: Remote sensing technologies for enhancing forest inventories: A review. Canadian Journal of Remote Sensing 42 (5): 619–641. https://doi.org/10.1080/07038992.2016.1207484
- Wilkes, P., A. Lau, M. Disney, K. Calders, A. Burt, J.G. de Tanago, H. Bartholomeus, B. Brede, M. Herold, 2017: Data acquisition considerations for terrestrial laser scanning of forest plots. Remote Sensing of Environment 196: 140–153. https://doi.org/10.1016/j.rse.2017.04.030

SUMMARY

This study evaluated the accuracy of the latest, high-end commercial personal laser scanner (PLS) in estimating diameter at breast height (DBH) and tree height in an old pedunculate oak (*Quercus robur* L.) stand. The research was conducted in the state-owned management unit Šiljakovačka Dubrava (Forest Office Velika Gorica, Forest Administration Zagreb, Croatian Forests Ltd.) in Central Croatia, in a 145-year-old oak stand. Three circular sample plots (20 m in radius each) were established, including 40 oak trees in total (Figure 1). Reference data were collected by detailed field measurements and terrestrial laser scanning (TLS). DBH was measured using a diameter tape, while TLS (FARO Focus Premium 150) was used as the reference for tree height. TLS data were acquired using a multi-scan approach from five scan positions per plot (Figure 3a), whereas PLS data were collected using FARO Orbis according to a predefined walking scheme (Figure 3b). Both scanners, along with their technical specifications, are presented in Figure 2 and Table 1.

Before extracting individual tree attributes, a pre-processing of the collected TLS and PLS data was carried out. TLS data were pre-processed (registration, georeferencing) using FARO SCENE v2025.1.1, while PLS data were pre-processed using FARO Connect v2025.1 (Figure 4). Processing of TLS and PLS data (point clouds) was performed in the same manner using LiDAR360 v8.1. After normalising the point clouds, DBH of each tree was semi-automatically estimated; firstly, by approximate determination of diameter by the operator, which was secondly approximated by the fit-by-circle method, i.e., by the software algorithm that approximates DBH using the least squares method to fit a circle from the x-y coordinates of input points. Stems fitted by the circle method were used as seed points for individual tree segmentation (Point Cloud Segmentation from Seed Points algorithm; Figure 5). Within the segmentation process, the heights (H) were automatically estimated and then manually checked for any inconsistencies or errors (Figure 6). The measured and estimated DBH and tree height values for each tree, obtained from field measurements, as well as TLS and PLS data, are provided in the appendix (Table A1).

The accuracy assessment compared PLS-derived attributes against reference data using the correlation coefficient (r), mean difference (MD) and root mean square error (RMSE). Results for DBH (Table 2) showed a strong correlation with reference values (r = 0.995), with deviations ranging from –0.99 cm to 3.02 cm. The MD was 0.62 cm (1.28 %), and the RMSE was 1.04 cm (2.13%). Figure 7 illustrates the slight, systematic overestimation of PLS-derived DBH. Tree height estimates (Table 2) were even more accurate, with deviations between –0.13 m and 0.92 m. The correlation with TLS reference data was r = 0.995. MD was 0.22 m (0.69%), and RMSE was 0.30 m (0.95%). Figure 8 demonstrates the close agreement between PLS and TLS estimates, again with a slight overestimation trend.

The results confirm the high accuracy and reliability of PLS data for both DBH and height estimation in an old oak stand. Minor biases can be attributed to structural and morphological characteristics of trees, such as thick and furrowed bark in old oaks, which may cause an overestimation of DBH. Overall, the findings align with previous studies (e.g., Jurjević et al. 2020, Hyypä et al. 2020, Vandendaele et al. 2022, Kokeza et al. 2024, 2025), which report a slight overestimation but high accuracy of PLS-derived tree attributes.

In conclusion, when high-end instruments are used, the PLS technology provides highly accurate and efficient estimates of DBH and tree height, demonstrating strong potential for integration into operational forest inventory. Further research across different stand types and conditions is recommended to establish best-practice guidelines for PLS data acquisition and processing.

KEY WORDS: personal laser scanning (PLS), LiDAR, diameter at breast height, tree height, forest inventory

DODATAK
APPENDIX

Tablica A1. Izmjerene i procijenjene vrijednosti atributa pojedinačnih stabla: DBH_{REF} – referentni prsni promjer izmjeren mjernom vrpcom, DBH_{PLS} – prsni promjer procijenjen iz PLS podataka, H_{TLS} – referentna visina stabala procijenjena iz TLS podataka, H_{PLS} – visina stabala procijenjena iz PLS podataka.
Table A1 Measured and estimated attribute values for individual trees: DBH_{REF} – reference diameter at breast height measured with a diameter tape, DBH_{PLS} – diameter at breast height estimated from PLS data, H_{TLS} – reference tree height estimated from TLS data, H_{PLS} – tree height estimated from PLS data.

ID stabla *Tree ID*	Ploha ***Plot***	Broj stabla ***Tree No***	X (°)	Y (°)	DBH_{REF} (cm)	DBH_{PLS} (cm)	H_{TLS} (m)	H_{PLS} (m)
1	4	1	465171,06	5058756,20	49,66	50,95	32,50	32,75
2	4	2	465172,91	5058753,32	39,79	40,14	31,54	31,83
3	4	3	465169,07	5058748,24	42,97	45,85	30,75	31,67
4	4	4	465170,62	5058738,49	45,84	46,00	30,25	30,55
5	4	5	465173,58	5058735,93	44,56	46,41	30,94	31,03
6	4	6	465160,68	5058735,86	35,01	36,43	25,92	26,64
7	4	7	465159,30	5058737,95	61,75	61,41	31,54	31,55
8	4	8	465163,65	5058748,07	45,20	48,22	30,87	31,51
9	4	9	465152,00	5058752,14	49,66	50,72	31,35	31,80
10	4	10	465156,58	5058756,62	49,02	49,28	32,02	32,26
11	4	11	465153,02	5058762,05	43,61	44,17	31,81	32,08
12	4	12	465159,18	5058764,83	42,34	43,34	32,35	32,82
13	4	13	465160,60	5058767,61	35,01	35,33	30,55	30,76
14	4	14	465167,35	5058761,55	51,57	51,53	34,15	34,33
15	4	15	465174,83	5058766,17	54,11	54,24	33,51	33,55
16	4	16	465176,37	5058764,38	52,20	52,16	33,67	33,71
17	5	1	465165,79	5058595,19	67,48	67,85	33,44	33,38
18	5	2	465159,81	5058581,65	34,38	35,45	30,40	30,41
19	5	3	465154,18	5058588,26	42,97	43,56	30,09	30,43
20	5	4	465153,90	5058591,96	33,74	34,12	26,36	26,66
21	5	5	465150,09	5058587,80	35,33	36,15	25,44	25,58
22	5	6	465153,60	5058578,85	53,16	53,97	32,38	32,56
23	5	7	465143,99	5058586,86	51,88	52,05	29,61	29,72
24	5	8	465138,72	5058581,80	53,16	52,17	30,48	30,60
25	5	9	465134,16	5058601,23	59,52	59,82	33,46	33,72
26	5	10	465150,50	5058597,55	41,38	41,27	31,15	31,26
27	5	11	465149,18	5058602,41	42,97	42,80	30,31	30,19
28	5	12	465158,50	5058597,54	46,15	46,72	32,50	32,69
29	5	13	465146,36	5058611,01	63,03	65,63	33,44	33,45
30	6	1	465036,49	5058594,31	65,25	64,75	35,07	35,23
31	6	2	465031,00	5058593,78	56,66	56,72	31,95	32,13
32	6	3	465032,67	5058599,18	41,38	42,39	30,20	30,41
33	6	4	465022,48	5058592,09	44,56	45,64	30,50	30,95
34	6	5	465019,59	5058594,40	44,25	44,58	31,93	32,16
35	6	6	465008,23	5058596,06	47,75	47,98	32,53	32,46
36	6	7	465002,94	5058587,40	60,48	61,07	33,27	33,27
37	6	8	464996,76	5058589,01	53,79	54,00	34,02	34,18
38	6	9	465005,87	5058580,18	47,75	48,25	33,18	33,32
39	6	10	465012,60	5058577,71	57,93	58,06	32,31	32,59
40	6	11	465022,40	5058581,78	55,70	56,67	31,59	31,75

https://doi.org/10.31298/sl.149.11-12.2

Izvorni znanstveni članci – Original scientific papers
Šumarski list, 11-12 (2025): 517-530

MORPHOLOGICAL AND ANATOMICAL DIVERSITY OF *Juniperus sabina* var. *balkanensis* IN THE CROATIAN DINARIC MOUNTAINS

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SUMMARY

Juniperus sabina var. *balkanensis* R.P.Adams et Tashev is a morphologically cryptic but genetically distinct tetraploid lineage, hypothesized to have originated through ancient hybridization between maternal diploid *Juniperus sabina* var. *sabina* and a paternal ancestor related to *Juniperus thurifera* L. Although its presence in Croatia has been confirmed, morphological and anatomical variability along the Dinaric range remains poorly understood. In this study, we analysed three natural populations from the Croatian Dinaric Alps (Biokovo and two sites on Velebit), comprising a total of 35 individuals. The aim was to assess intra- and inter-population variability, sex-based differences, and population × sex interactions, focusing on five vegetative traits and four cone traits. In addition, we examined how geographic position, elevation, and environmental gradients form morphological variation. Our results revealed significant differentiation among individuals within populations for all measured traits, although variability was generally low to moderate, consistent with previous genetic studies. Statistically significant differences between populations were confirmed for four traits. Multivariate analyses provided further insight: PCA identified scale leaf number and length, as well as cone size and seed number, which are the traits most responsible for population differentiation, while RDA demonstrated that these differences are structured by environmental and spatial gradients rather than random variation. Low to moderate intra-population variability and pronounced inter-population differences may reflect limited gene flow, clonal propagation, and inbreeding within fragmented habitats. Sex-based differences were observed in scale leaf number and length; however, given the limited sample size and the presence of both monoecious and dioecious shrubs, further research is needed to draw robust conclusions regarding sexual dimorphism. Overall, our findings contribute to a clearer understanding of the morphological variability of *J. sabina* var. *balkanensis*. Given its restriction to high-altitude, xerothermic habitats in the Dinaric Alps, this variety represents a valuable component of mountain biodiversity and should be considered in future conservation efforts targeting relict shrubland communities.

KEY WORDS: Dinaric Alps, cone morphology, leaf scale anatomy and morphology, morphometric analysis, phenotypic variability, population variation, sexual dimorphism

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INTRODUCTION

Juniperus sabina L., commonly known as savin juniper or savin, is a morphologically variable, predominantly dioecious shrub belonging to the monophyletic section *Sabina* within the genus *Juniperus* L. (Cupressaceae) (Mao et al. 2010). It is widely distributed across mountainous regions of southern and central Europe, extending eastward into western and central Asia (Adams 2014). The species typically occupies dry, rocky habitats at mid to high elevations, where it exhibits remarkable ecological plasticity and tolerance to drought, cold, and poor soils. Despite its broad range, *Juniperus sabina* often forms small, scattered populations, suggesting a refugial distribution shaped by complex biogeographic and climatic histories. Previous studies have revealed weak geographical structuring in its morphology (Mazur et al. 2021), despite significant genetic differentiation across its range (Jadwiszczak et al. 2023, 2024), pointing to a long history of gene flow and relatively recent population isolation. Moreover, genome size variation and polyploidy have been documented within the species (Adams et al. 2016, 2017, 2018; Farhat et al. 2019) further complicating its taxonomic and evolutionary interpretation.

Recent taxonomic treatments recognize five infraspecific taxa within *Juniperus sabina*, reflecting its wide ecological amplitude and complex evolutionary history. According to the Plants of the World Online database maintained by Kew Science (2025), the accepted varieties include: var. *sabina*, var. *balkanensis* R.P.Adams et Tashev, var. *arenaria* (E.H.Wilson) Farjon, var. *davurica* (Pall.) Farjon, and var. *mongolensis* R.P.Adams. Of these, three varieties – *davurica*, *mongolensis*, and *arenaria* – are distributed across the eastern part of the species' range in Central Asia, while two – *sabina* and *balkanensis* – are confined to Europe and western Anatolia. The European varieties are of particular interest due to their overlapping morphological traits, contrasting ploidy levels, and distinct biogeographic histories.

The most recent and taxonomically significant development concerns the recognition of *Juniperus sabina* var. *balkanensis*, a tetraploid lineage (specifically an allotetraploid) hypothesized to have originated through ancient hybridization between maternal diploid *Juniperus sabina* var. *sabina* and a paternal ancestor related to *Juniperus thurifera* L. (Adams et al. 2016). This variety has since been documented across the Balkan Peninsula, western Turkey, and parts of the Apennines, including newly confirmed populations in Croatia (Adams et al. 2018). Molecular studies using chloroplast DNA, nuclear microsatellites, and SNP markers have consistently supported the genetic distinctiveness of var. *balkanensis* (Jadwiszczak et al. 2023, 2024), despite its morphological similarity to var. *sabina* (Mazur et al. 2021). The near-parapatric distribution of the two varieties, coupled with their contrasting ecological preferences – particularly in relation to soil potassium content and drought tolerance – suggest a complex evolutionary trajectory shaped by hybridization, polyploidization, and climatic filtering. Var. *sabina* occupies cooler and wetter environments, whereas var. *balkanensis* is adapted to warmer, drier habitats with potassium-rich soils (Jadwiszczak et al. 2023, 2024).

In Croatia, *Juniperus sabina* var. *balkanensis* forms distinctive shrubland communities classified within the EUNIS habitat system as F2.2 – evergreen alpine and subalpine heath and scrub. These habitats are typically found above 900 m a.s.l. in the Dinaric Alps (Figure 1), occupying xerothermic karst terrains with shallow, skeletal soils developed on limestone and dolomite. The Croatian populations of *Juniperus sabina* var. *balkanensis* are characterized by dense, prostrate growth forms that inhibit the development of continuous grass cover, thereby creating patchy microhabitats within mosaics of dry grasslands and rocky outcrops. The vegetation includes a suite of xerophilous and thermophilus species such as *Juniperus communis* var. *saxatilis* Pall., *Amelanchier ovalis* (Willd.) Borkh., *Rhamnus saxatilis* Jacq., and *Arctostaphylos uva-ursi* (L.) Spreng., alongside grassland elements like *Sesleria juncifolia* Suffren, *Festuca* spp., and *Stipa* spp. These shrublands represent a transitional successional stage toward *Fagus sylvatica* L. or *Pinus nigra* J.F. Arnold forests, with *Juniperus sabina* var. *balkanensis* playing an important role in soil stabilization and organic matter accumulation through its extensive root system and needle litter (Topić and Vukelić 2009).

Although the presence of the tetraploid *Juniperus sabina* var. *balkanensis* in Croatia has been confirmed (Adams et al. 2018), its morphological and anatomical variability along the Dinaric range remains poorly understood. Previous studies have focused exclusively on a single population from the Velebit Mountain (Mazur et al. 2021), leaving a significant gap in our knowledge of the species' intraspecific diversity in this region. In the present study, we examined three natural populations – two from different localities on the Velebit Mountain and one from the Biokovo Mountain – representing the southernmost and ecologically contrasting segments of the Croatian Dinarides. In contrast to the widespread *Juniperus communis* var. *saxatilis*, which dominates subalpine scrublands across the Dinaric karst, *Juniperus sabina* var. *balkanensis* is relatively rare and spatially restricted. Its occurrence in Croatia is limited to isolated patches within high-altitude, xerothermic habitats,

Figure 1 Habitat of the Biokovo population, showing scattered shrubs of *Juniperus sabina* var. *balkanensis* among dominant shrubs of *Juniperus communis* var. *saxatilis*.

making it a valuable element of regional biodiversity. The Dinaric Alps, with their pronounced ecological gradients and floristic heterogeneity, thus provide a unique setting for investigating population-level variation in relict and alpine taxa.

This study aimed to assess the morphological and anatomical variability of vegetative traits (scale leaves and shoots), as well as the morphological diversity of cones within and among populations. Special attention was given to differences between male and female shrubs based on vegetative traits. Furthermore, we explored the extent to which population structure is influenced by geographic position, elevation, and other environmental factors, with the goal of identifying patterns of local adaptation and potential drivers of phenotypic divergence.

MATERIALS AND METHODS

Study area and plant material

In the spring of 2025, plant material of *Juniperus sabina* var. *balkanensis* was collected for anatomical and morphometric research from three natural populations in Croatia (Figure 2, Table 1): Veliki Alan and Mali Alan on the Velebit Mountain, and one on the Biokovo Mountain. A total of 35 individual shrubs were sampled – 13 from Veliki Alan, 12 from Mali Alan, and 10 from Biokovo – comprising 16 female and 19 male plants (Table 1). Each shrub was georeferenced using GPS to ensure precise spatial documentation and support future environmental interpretation. From every shrub, a single branch approximately 20–30 cm in length was clipped to examine the anatomical structure and morphometry of scale-leaves. On female plants, berry-like seed cones were also collected, with around 10 cones taken per shrub. All samples were immediately placed in ziplock plastic bags or small containers in the field to preserve freshness and prevent desiccation. Each sample was labelled with a unique identifier to ensure accurate tracking. The collected material was then transported to the Laboratory for Morphological Research at the Department of Forest Genetics, Dendrology and Botany, University of Zagreb Faculty of Forestry and Wood Technology, for further analysis. Prior to analysis, all plant material was stored under refrigeration to maintain sample integrity. Additionally, representative specimens from each locality were prepared as herbarium vouchers and deposited in the DEND Herbarium at the University of Zagreb Faculty of Forestry and Wood Technology.

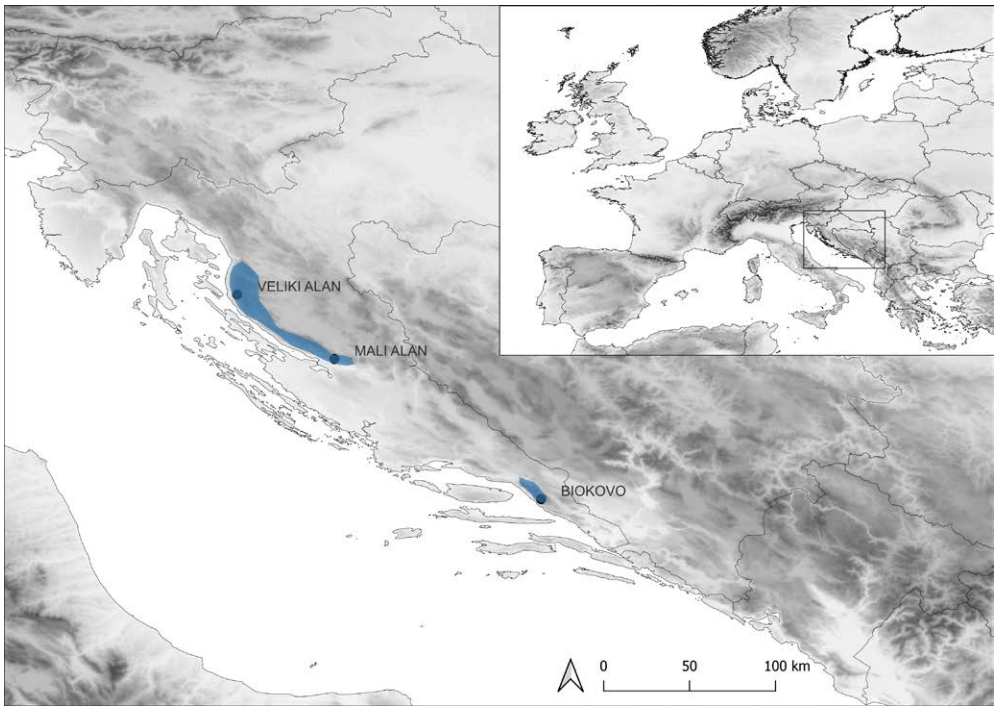

Figure 2 Geographic distribution of three sampled populations of *Juniperus sabina* var. *balkanensis* in the Croatian Dinaric Alps, with the overall range of the taxon in Croatia shown in blue.

Table 1 Populations of *Juniperus sabina* var. *balkanensis* from the Croatian Dinaric Alps, with geographic coordinates, elevation, number of analysed shrubs (total, male and female), and bioclimatic variables (BIO1, BIO3, BIO4, BIO12, BIO15, SOLAR) used in the Redundancy Analysis (RDA). Bioclimatic variables were calculated as population means based on individual sampling coordinates, while elevation is presented as mean values with ranges. Although BIO12 (annual precipitation) is shown in the table to facilitate interpretation, it was excluded from Redundancy Rnalysis (RDA) due to collinearity. Bioclimatic variables: BIO1 (mean annual temperature), BIO3 (isothermality), BIO4 (temperature seasonality), BIO12 (annual precipitation), BIO15 (precipitation seasonality), and SOLAR (annual solar radiation).

Population	Latitude (°)	Longitude (°)	Total shrubs	Male plants	Female plants	Elevation (m a.s.l.)	BIO1 (°C)	BIO3	BIO4	BIO12 (mm)	BIO15	SOLAR (Wh/m²)
Veliki Alan	44.71493	14.96306	13	7	6	1210 (1030–1312)	6.09	33.1	620	1622	26.2	12788
Mali Alan	44.26415	15.64471	12	7	5	860 (804–906)	8.87	32.9	662	1158	27.1	13231
Biokovo	43.28346	17.09259	10	5	5	1149 (1120–1243)	8.50	34.3	597	940	27.8	13709
Total			35	19	16							

Morphological and anatomical characterization of shoots, scale leaves, and cones

Morphological analysis of scale leaves and shoots was performed using both stereo and compound microscopy. Macrophotographs of freshly collected material were obtained with a stereo microscope (Olympus SZX12) equipped with a digital camera (Olympus EP50), while microphotographs of leaf cross-sections were taken with a compound microscope (Olympus BX41) fitted with a digital camera (Olympus LC35). Vegetative morphometric traits – including the number of lateral (NLS) and facial (NFS) scale leaf pairs per 1 cm of shoot length, facial leaf length (FSL), and overall shoot width (SW) – were measured at a standardized distance of 0.5 cm from the shoot apex. These measurements were performed using the integrated On-Screen Display (OSD) software of the Olympus EP50 camera. For anatomical analysis, epidermal thickness (ET) was quantified using PRECiV Capture software (version 1.2, Build 27732) (PRECiV™ 2021), based on calibrated microphotographs of transverse leaf sections.

Cone dimensions were measured using a digital calliper (Alpha Tools®, Bahag AG, Germany, ±0.1 mm). For each cone, three measurements were taken: cone length (CL), cone width (CW), and cone thickness (CT). After these morphometric measurements, the total number of seeds contained in each cone (NS) was determined.

Statistical analysis

Morphological variability of shoots, scale leaves and seed cones was assessed using descriptive statistical parameters. For each trait, the arithmetic mean, standard deviation, minimum and maximum values, and the coefficient of variation (CV, %) were calculated. For scale leaf traits these metrics were computed separately

for male and female individuals, as well as for each population and for the total dataset.

Morphometric traits of vegetative shoots and cones were analysed using linear mixed-effects models in R (R Core Team 2025). The analysis was performed using the lme4 package (Bates et al. 2025), which allows specification of both fixed and random effects. For shoot-related traits, the model included fixed effects of sex and population, as well as their interaction, while shrub nested within population was treated as a random effect. For cone-related traits, fixed effects included population, and shrub nested within population was modelled as a random effect. Model fitting was conducted using the lmer() function, and the significance of fixed effects was assessed via Type III ANOVA using the car package (Fox and Weisberg 2019).

Principal Component Analysis (PCA) was conducted to examine patterns of variation among shrubs and populations based on morphometric traits. PCA was performed separately for vegetative and cone morphological traits using the FactoMineR (Lê et al. 2008) and Factoextra (Kassambara and Mundt 2020) packages in R Statistical Software (v4.4.0; R Core Team 2025). Prior to analysis, all trait variables were standardized (z-transformed) to ensure comparability and reduce scale effects. For vegetative traits, PCA was based on five variables, while cone traits were analysed using four. Eigenvalues, explained variance, and variable loadings were extracted to assess component significance and trait contributions. Components with eigenvalues greater than one were retained for interpretation. Population-level patterns were assessed based on individual scores along the first two principal components, and visualized using biplots that simultaneously display trait orientation and individual clustering.

To assess the influence of environmental and geographic factors on morphological variation in *Juniperus sabina* var. *balkanensis*, we performed Redundancy Analysis (RDA) using the vegan package (v2.6-4; Oksanen et al. 2022) within R Statistical Software (v4.4.0; R Core Team 2025). Morphological traits were divided into two sets: vegetative traits and cone traits, each analysed separately using constrained ordination. Prior to analysis, all morphological variables were Hellinger-transformed to reduce scale dependency and meet assumptions of linear ordination. Traits with high intercorrelation ($r > 0.85$) were excluded to avoid redundancy, retaining only those with clear population-level differentiation. Environmental predictors included bioclimatic variables (BIO1–BIO19), solar radiation, and altitude. Bioclimatic data were retrieved from WorldClim v2.1 (Fick and Hijmans 2017) at 30 arc-second resolution, while altitude was obtained via GPS measurements. To reduce multicollinearity, we performed a correlation analysis among environmental variables and excluded all variables with pairwise Pearson correlation coefficients exceeding ±0.9. Final predictor sets were selected separately for each trait group based on ecological relevance and statistical independence. All predictors were standardized (z-transformed) prior to ordination. Geographic predictors included latitude and longitude. To partition the variation attributable to environment and geography, we constructed three RDA models for each trait group: (1) a full RDA model including both environmental and geographic predictors; (2) a partial RDA isolating environmental effects conditioned on geography (environment | geography); (3) a partial RDA isolating geographic effects conditioned on environment (geography | environment). Model significance was assessed using permutation tests (999 iterations), and the adjusted R^2 values were used to evaluate explanatory power.

Ordination results from both PCA and RDA analyses were visualized using the ggplot2 package (Wickham 2016) in R Statistical Software (v4.4.0), with enhancements provided by ggrepel (Slowikowski 2024) for label clarity and ggsci (Xiao 2024) for consistent colour schemes. All plots were standardized for axis scaling and annotated to highlight population-level patterns and trait contributions. Only the first two axes were displayed in each ordination, as they captured the majority of explained variation.

RESULTS

Variation in vegetative traits

Across all individuals, scale leaf traits exhibited low to moderate variability (Table 2). The number of facial scale leaf pairs (NFS) ranged from 5 to 15, with a mean of 7.40 ± 1.15, while lateral scale leaf pairs (NLS) ranged from 4.5 to 15, averaging 7.26 ± 1.16 per centimetre of shoot length. Shoot width (SW) was relatively stable (1.32 ± 0.12 mm, range: 1.03–1.72 mm), whereas facial leaf length (FSL) showed greater variation (1.65 ± 0.28 mm, range: 1.05–2.84 mm). Epidermal thickness (ET) ranged from 11.00 to 22.18 μm, with a mean of 16.79 ± 1.62 μm. Coefficients of variation (CV) below 10% were observed for shoot width (8.73%) and epidermal thickness (9.67%), while higher CVs were recorded for facial scale leaf number (15.53%), lateral scale leaf number (16.00%), and scale leaf length (16.68%).

Morphological traits of scale leaves varied across the three populations – Veliki Alan, Mali Alan, and Biokovo – with notable differences in both size and number (Table 2). The Biokovo population exhibited the highest mean

values for both facial (8.09) and lateral (7.92) scale leaf pairs, with broader ranges (facial: 6–15; lateral: 6–15) and slightly higher variability in lateral leaf count (CV = 15.30%). In contrast, Mali Alan had the lowest mean values (facial: 7.05, lateral: 6.87), though variability remained comparable (CV ≈ 14.3–14.6%). Shoot width was consistent across populations, ranging from 1.31 to 1.34 mm, with low CVs (<10%). The shortest facial scale leaves were recorded in the Biokovo population (mean = 1.50 mm, CV = 11.35%), while Mali Alan had the longest scale leaves (mean = 1.73 mm, CV = 16.11%). Veliki Alan showed similar values to Mali Alan (mean = 1.70 mm, CV = 17.24%), indicating a shared trend in leaf elongation. Epidermal thickness was highest in Biokovo (mean = 17.21 µm, range: 11.00–22.18 µm), with slightly greater variability (CV = 11.65%) compared to Veliki Alan (mean = 16.46 µm, CV = 8.52%) and Mali Alan (mean = 16.78 µm, CV = 8.30%).

Variation in seed cone traits

Among the four cone traits analysed across studied populations (Table 3), the number of seeds per cone (NS) emerged as the most variable trait (CV = 42.65%). In contrast, cone length (CL) and cone width (CW) showed relatively low variability (CV = 10.93% and 11.53%, respectively), suggesting morphological stability in these dimensions. Cone thickness (CT) displayed intermediate variability (CV = 16.22%).

Among the four cone traits analysed across *Juniperus sabina* var. *balkanensis* populations (Table 3), cone length (CL) showed the most pronounced differences in mean values. Biokovo had significantly shorter cones (mean = 5.47 mm) compared to Veliki Alan (6.16 mm) and Mali Alan (6.41 mm). In contrast, cone width (CW) remained relatively consistent across populations, ranging from 6.11 to 6.36 mm, and cone thickness (CT) from 5.50 to 5.82 mm. The number of seeds per cone (NS) was highest in Biokovo (mean = 2.42), followed by Mali Alan (2.12) and Veliki Alan (1.84), suggesting slight reproductive differentiation among sites.

Sexual dimorphism

Sex-based differences were observed across several measured traits (Table 2). The number of facial scale leaf pairs (NFS) was consistently higher in female shrubs across all populations. For example, in the Biokovo population, female shrubs averaged 8.52 pairs compared

Table 2 Descriptive statistics of vegetative traits in *Juniperus sabina* var. *balkanensis* across populations and sexes. Descriptive parameters: $\bar{x}$ – arithmetic mean; Min – minimum value observed within the sample; Max – maximum value observed within the sample; SD – standard deviation; CV (%) – coefficient of variation. Acronyms of vegetative morphometric traits: NFS – number of facial scale pairs; NLS – number of lateral scale pairs; SW – shoot width; FSL – facial scale length; ET – epidermis thickness.

Trait	Descriptive parameter	Population									*Juniperus sabina*		
		Veliki Alan			Mali Alan			Biokovo					
		Total	Male	Female	Total	Male	Female	Total	Male	Female	Total	Male	Female
NFS	$\bar{x}$	7.17	6.76	7.59	7.05	6.87	7.30	8.09	7.66	8.52	7.40	7.05	7.79
	Min	5.00	5.00	6.00	5.00	5.00	5.00	6.00	6.00	7.00	5.00	5.00	5.00
	Max	10.00	9.00	10.00	10.00	9.00	10.00	15.00	9.00	15.00	15.00	9.00	15.00
	SD	1.06	1.05	0.90	1.01	0.85	1.17	1.12	0.73	1.27	1.15	0.96	1.22
	CV (%)	14.75	15.5	11.85	14.34	12.31	16.02	13.84	9.55	14.95	15.53	13.66	15.61
NLS	$\bar{x}$	7.12	6.78	7.45	6.87	6.69	7.11	7.92	7.42	8.42	7.26	6.93	7.65
	Min	4.50	4.50	6.00	4.50	5.00	4.50	6.00	6.00	6.00	4.50	4.50	4.50
	Max	10.50	9.00	10.50	9.00	9.00	9.00	15.00	9.00	15.00	15.00	9.00	15.00
	SD	1.04	1.05	0.92	1.01	0.82	1.18	1.21	0.77	1.36	1.16	0.94	1.27
	CV (%)	14.56	15.44	12.34	14.65	12.28	16.65	15.30	10.40	16.20	16.00	13.56	16.60
SW (mm)	$\bar{x}$	1.34	1.34	1.34	1.32	1.32	1.31	1.31	1.32	1.31	1.32	1.32	1.32
	Min	1.03	1.03	1.15	1.06	1.07	1.06	1.11	1.11	1.12	1.03	1.03	1.06
	Max	1.60	1.60	1.53	1.60	1.56	1.60	1.72	1.72	1.55	1.72	1.72	1.60
	SD	0.11	0.13	0.09	0.11	0.09	0.13	0.13	0.15	0.11	0.12	0.12	0.11
	CV (%)	8.44	9.74	7.00	8.12	6.75	9.81	9.71	11.08	8.19	8.73	9.10	8.33
FSL (mm)	$\bar{x}$	1.70	1.82	1.58	1.73	1.77	1.69	1.50	1.52	1.48	1.65	1.71	1.58
	Min	1.12	1.24	1.12	1.16	1.33	1.16	1.05	1.05	1.11	1.05	1.05	1.11
	Max	2.82	2.82	2.02	2.84	2.84	2.57	1.87	1.86	1.87	2.84	2.84	2.57
	SD	0.29	0.33	0.18	0.28	0.25	0.31	0.17	0.18	0.16	0.28	0.29	0.24
	CV (%)	17.24	18.18	11.61	16.11	14.31	18.32	11.35	11.57	11.12	16.68	17.03	15.05
ET (µm)	$\bar{x}$	16.46	16.09	16.84	16.78	16.77	16.78	17.21	17.15	17.27	16.79	16.65	16.95
	Min	12.49	12.49	14.36	13.09	13.09	14.27	11.00	11.00	13.07	11.00	11.00	13.07
	Max	20.24	20.24	19.57	20.27	20.27	20.00	22.18	20.05	22.18	22.18	20.27	22.18
	SD	1.40	1.60	1.07	1.39	1.38	1.43	2.00	2.18	1.83	1.62	1.75	1.46
	CV (%)	8.52	9.93	6.34	8.30	8.21	8.51	11.65	12.71	10.62	9.67	10.49	8.62

Table 3 Descriptive statistics for analysed cone traits for *Juniperus sabina* var. *balkanensis*. Descriptive parameters: $\bar{x}$ – arithmetic mean; Min – minimum value observed within the sample; Max – maximum value observed within the sample; SD – standard deviation; CV (%) – coefficient of variation. Acronyms of cone morphometric traits: CL – cone length; CW – cone width; CT – cone thickness; NS – number of seeds per cone.

Trait	Descriptive parameter	Veliki Alan	Mali Alan	Biokovo	Total
CL (mm)	$\bar{x}$	6.16	6.41	5.47	6.02
	Min	5.34	4.91	4.33	4.33
	Max	7.20	7.34	6.64	7.34
	SD	0.45	0.53	0.60	0.66
	CV (%)	7.23	8.22	10.92	10.93
CW (mm)	$\bar{x}$	6.20	6.11	6.36	6.11
	Min	4.50	4.85	4.99	4.50
	Max	8.18	7.78	8.18	7.78
	SD	0.72	0.74	0.70	0.71
	CV (%)	11.65	12.13	11.07	11.53
CT (mm)	$\bar{x}$	5.70	5.50	5.82	5.79
	Min	4.09	4.61	4.45	4.09
	Max	7.82	6.53	7.09	7.82
	SD	0.72	0.50	0.61	0.94
	CV (%)	12.62	9.12	10.54	16.22
NS	$\bar{x}$	1.84	2.12	2.42	2.13
	Min	1.00	1.00	1.00	1.00
	Max	4.00	4.00	4.00	4.00
	SD	0.71	0.92	0.99	0.91
	CV (%)	38.60	43.29	40.98	42.65

to 7.66 in male shrubs, while in the Veliki Alan population the difference was 7.59 vs. 6.76. A similar pattern was found for lateral scale leaves (NLS), with mean values in female shrubs ranging from 7.11 to 8.42, and in male shrubs from 6.69 to 7.42.

Shoot width (SW) showed minimal variation between sexes, with nearly identical mean values (1.31–1.34 mm) and low coefficients of variation (CV < 10%) in both groups. In contrast, facial scale leaf length (FSL) was consistently greater in male shrubs. In the Mali Alan population, mean FSL was 1.77 mm in male shrubs compared to 1.69 mm in female shrubs, whereas in Veliki Alan the difference was even more pronounced (1.82 mm vs. 1.58 mm).

Epidermal thickness (ET) was slightly higher in female shrubs across all populations. In the Biokovo population, female shrubs reached a mean of 17.27 µm, compared to 17.15 µm in male shrubs, with similar trends observed in Veliki Alan (16.84 µm vs. 16.09 µm). In the Mali Alan population, however, epidermal thickness was nearly identical between female and male shrubs (16.78 µm vs. 16.77 µm).

Results of the General Linear Model (GLM) for vegetative and cone traits

Populations and sexes differed significantly in three traits (Table 4): the number of facial scale leaf pairs (NFS), the number of lateral scale leaf pairs (NLS), and the facial scale leaf length (FSL). Population effects explained 16.94%, 15.12%, and 14.45% of the total variance for these traits, respectively, while sex contributed 14.52%, 13.37%, and 6.59%. In contrast, shoot width (SW) and epidermal thickness (ET) showed no significant differences between populations or sexes, with population-level effects explaining only 0–3.15% and sex effects below 0.40%. These traits appear morphologically stable across broader spatial and habitat gradients.

The interaction between population and sex was non-significant in all cases (Table 4), contributing 0% to the total variance, suggesting that sex-related differences were consistent across populations and not context-dependent.

Shrubs nested within populations accounted for a substantial portion of the variance across all traits (Table 4), ranging from 15.02% (ET – epidermal thickness) to 28.42% (NLS – the number of lateral scale leaf pairs), thus highlighting pronounced individual-level variability within populations. Residual error explained the remaining variation, ranging from 43.09% to 81.44%, depending on the trait, likely reflecting both measurement noise and unaccounted biological complexity (e.g., within-shrub variability).

Significant variation in cone length (CL) was observed among the studied *Juniperus sabina* var. *balkanensis* populations (Table 5), accounting for 43.68% of the

Table 4 Results of the General Linear Model (GLM) for vegetative traits. Acronyms of vegetative morphometric traits: NFS – number of facial scale pairs; NLS – number of lateral scale pairs; SW – shoot width; FSL – facial scale length; ET – epidermis thickness. df – degrees of freedom; F – F-test in GLM; *p* – significance of GLM's F-test. *** significant at $p < 0.001$; ** significant at $0.001 < p < 0.01$; * significant at $0.01 < p < 0.05$; ns depicts non-significant values ($p > 0.05$).

Trait	Components of the variance	df	F	*p*-value	%
NFS	Population	2	7.37	**	16.94
	Sex	1	8.92	**	14.52
	Population × Sex	2	0.36	ns	0.00
	Shrub (Population)	29	6.84	***	24.76
	Error				43.78
NLS	Population	2	6.16	**	15.12
	Sex	1	7.42	*	13.37
	Population × Sex	2	0.44	ns	0.00
	Shrub (Population)	29	7.77	***	28.42
	Error				43.09
SW	Population	2	0.36	ns	0.00
	Sex	1	0.08	ns	0.00
	Population × Sex	2	0.03	ns	0.00
	Shrub (Population)	29	5.10	***	26.30
	Error				73.70
FSL	Population	2	6.57	**	14.45
	Sex	1	4.99	*	6.59
	Population × Sex	2	1.33	ns	1.52
	Shrub (Population)	29	5.95	***	26.11
	Error				51.33
ET	Population	2	2.39	ns	3.15
	Sex	1	1.18	ns	0.39
	Population × Sex	2	0.76	ns	0.00
	Shrub (Population)	29	2.84	***	15.02
	Error				81.44

total variance, while within-population variation was considerably lower (8.50%). In contrast, cone width (CW) and cone thickness (CT) showed no significant inter-population differences, with most of the variation attributed to within-population variability and residual error. The number of seeds per cone (NS) exhibited relatively low within-population variation (10.91%), whereas differences among populations were not statistically significant. These findings indicate that cone length (CL) is the most spatially and environmentally structured trait, while cone width (CW) and thickness (CT) are primarily influenced by individual-level variation within populations.

Principal Component Analysis (PCA)

Principal Component Analysis (PCA) based on five vegetative traits revealed that the first two principal components had eigenvalues greater than one and together explained 80.3% of the total variance. The first principal component (PC1) accounted for 58.0% of the

Table 5 Results of the General Linear Model (GLM) for cone traits. Acronyms of cone morphometric traits: CL – cone length; CW – cone width; CT – cone thickness; NS – number of seeds per cone. df – degrees of freedom; F – F-test in GLM; *p* – significance of GLM's F-test. *** significant at $p < 0.001$; ** significant at $0.001 < p < 0.01$; * significant at $0.01 < p < 0.05$; ns depicts non-significant values ($p > 0.05$).

Trait	Variance component	F	*p*-value	%
CL	Among populations	17.45	***	43.68
	Within populations	2.78	***	8.50
	Error			47.83
CW	Among populations	0.86	ns	0.00
	Within populations	2.63	***	13.61
	Error			86.39
CT	Among populations	0.54	ns	0.00
	Within populations	10.31	***	46.33
	Error			53.67
NS	Among populations	2.59	0.12	6.11
	Within populations	2.31	*	10.91
	Error			82.98

variation and was strongly positively correlated with the number of facial scale leaves pairs (NFS, r = 0.974) and lateral scale leaves pairs (NLS, r = 0.944), while showing a strong negative correlation with facial scale leaf length (FSL, r = -0.907). The second principal component (PC2), which explained an additional 22.3% of the variance, was primarily associated with shoot width (SW, r = -0.831) and epidermal thickness (ET, r = -0.594), both showing moderate to strong negative loadings. The remaining components (PC3–PC5) had eigenvalues below one and together explained the remaining 19.7% of the total variance (PC3 = 15.1%, PC4 = 4.3%, PC5 = 0.3%), but were not considered informative for interpretation. Despite partial overlap among *Juniperus sabina* var. *balkanensis* shrubs, the PCA biplot revealed a clear spatial separation of populations (Figure 3A). Individuals from the Biokovo population clustered predominantly on the right side of the diagram, characterized by higher numbers of facial (NFS) and lateral (NLS) scale leaf pairs. In contrast, shrubs from Mali Alan and Veliki Alan (Velebit Mountain) populations grouped on the left side, distinguished by longer facial scale leaves (FSL).

Similar to the PCA based on vegetative traits, the analysis of cone morphology also revealed structured variation among populations (Figure 3B). The first two principal components had eigenvalues greater than one and together explained 81.7% of the total variance. PC1 accounted for 50.5% and was strongly negatively correlated with cone thickness (CT, r = –0.864), cone width (CW, r = –0.800), and the number of seeds per cone (NS, r = –0.756), indicating that individuals with higher scores on this axis tend to have smaller cones with fewer seeds. PC2 explained an additional 31.2% of the variance and was strongly negatively associated with cone length (CL, r = –0.934), while also showing a moderate positive correlation with seed number (NS, r = 0.578). The remaining components (PC3 and PC4) had eigenvalues below one and together accounted for the remaining 18.3% of the variance, indicating that most of the morphological variation in cone traits is captured by the first two axes. Unlike the PCA with vegetative traits, where population separation was more gradual, the biplot based on cone traits revealed a pronounced divergence along the second principal component. Shrubs from the Biokovo population formed a clearly distinct cluster on the upper side of the diagram, characterized by shorter cones with a larger number of seeds, whereas individuals from Mali Alan and Veliki Alan (the Velebit Mountain) grouped together on the lower side, defined by longer cones with fewer seeds per cone.

Redundancy Analysis (RDA)

To examine how environmental and spatial gradients influence vegetative morphology in *Juniperus sabina* var. *balkanensis*, we performed Redundancy Analysis (RDA) using eight explanatory variables: six ecological (BIO1 – mean annual temperature, BIO3 – temperature isothermality, BIO4 – temperature seasonality, BIO15 – precipitation seasonality, solar radiation and altitude) and two geographical (latitude and longitude). Of the five vegetative traits initially considered, four were retained for analysis due to high collinearity between the number of lateral (NLS) and facial (NFS) scale leaf pairs. The full model approached statistical significance (F = 2.009, p = 0.058) and explained 38.2% of the variance observed in vegetative traits (Table 6). The first constrained axis (RDA1) accounted for 85.9% of the explained variation, while the second axis (RDA2) contributed an additional 13.5% (Figure 3C). The remaining axes explained negligible amounts and were not further considered. Partial RDA models revealed that environmental variables ($pRDA_{env}$) accounted for a larger portion of the variation (R^2 = 0.206) than geographical variables ($pRDA_{geo}$, R^2 = 0.011), which were not significant. Several environmental and geographical predictors showed statistically significant associations with vegetative morphological variation, as indicated by permutation tests ($p < 0.05$). These included temperature isothermality (BIO3), temperature seasonality (BIO4), solar radiation (SOLAR), latitude, and longitude. Marginally significant effects were observed for precipitation seasonality (BIO15) and altitude ($p < 0.1$), while mean annual temperature (BIO1) was not significant. In the ordination space (Figure 3C), most of these significant predictors were strongly aligned with the first constrained axis (RDA1), particularly BIO3, BIO4, and SOLAR, which exhibited high negative loadings. Latitude and longitude also showed strong projections along RDA1, suggesting that both environmental and spatial gradients contribute to the structuring of vegetative traits. RDA2 captured more subtle variation, with weaker associations to the included predictors.

In the second model, we examined how cone morphology responds to ecological and spatial gradients (Figure 3D, Table 7). Te model included five explanatory variables: mean annual temperature (BIO1), temperature isothermality (BIO3), altitude, latitude, and longitude. The full RDA model was statistically significant (F = 4.1784, p = 0.001), explaining 67.6% of the variability observed in cone traits (adjusted R^2 = 0.514). Variance partitioning using partial RDA revealed that environmental variation independent of geography accounted for 24.3% of the trait variance (adjusted R^2 = 0.169, p = 0.001), while the unique effect of geography – after controlling for environmental factors – explained only 13.1% and was not statistically significant (adjusted R^2 = 0.083, p = 0.14). Among the predictors, the environmental variable temperature isothermality (BIO3), along with latitude and

longitude, exhibited strong and statistically significant associations with cone traits ($p < 0.01$). These predictors were predominantly aligned with the first RDA axis, which captured 92.2% of the explained variation. In contrast, RDA2 accounted for only 6.4% and did not show strong associations with any individual predictor.

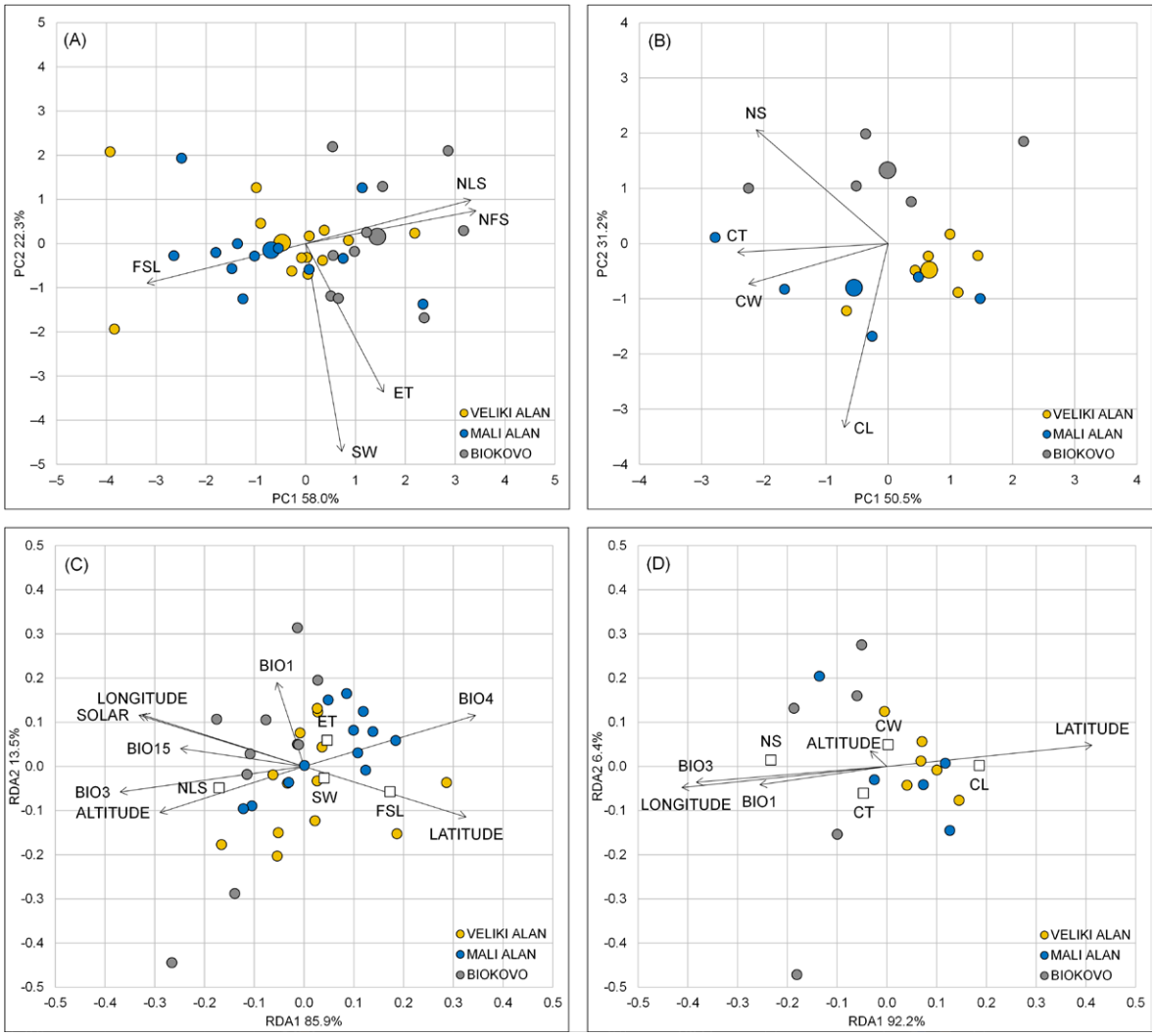

Figure 3 Multivariate ordination analyses (PCA and RDA) of vegetative and cone traits in *Juniperus sabina* var. *balkanensis* populations from the Croatian Dinaric Alps. (A–B) Principal Component Analyses (PCA) showing differentiation among populations based on vegetative (A) and cone traits (B). Individuals are represented as coloured points grouped by population, with arrows indicating the direction and magnitude of trait loadings. (C–D) Redundancy Analyses (RDA) illustrating population-level variation in vegetative (C) and cone traits (D) in relation to environmental and geographic gradients. Circles denote individuals grouped by population, squares represent morphological traits, and vectors show the strength and orientation of environmental and geographical predictors. Acronyms for environmental variables are defined in Table 1; acronyms for morphological and anatomical traits are listed in Tables 2 and 3.

Table 6 Performance metrics for full and partial RDA models assessing the effects of environmental and geographic predictors on vegetative morphological variation in *Juniperus sabina* var. *balkanensis*. Adjusted R^2, F-values, and *p*-values are based on permutation tests with 999 iterations.

Model	Predictors/effect	R^2	R^2_{adj}	F–value	*p*-value
RDA_{full}	Environment + Geography	0.382	0.192	2.0092	0.058
$pRDA_{env}$	Environment | Geography	0.206	0.068	1.4465	0.213
$pRDA_{geo}$	Geography | Environment	0.011	-0.044	0.2326	0.870

Table 7 Performance metrics for full and partial RDA models assessing the effects of environmental and geographic predictors on cone morphological variation in *Juniperus sabina* var. *balkanensis*. Adjusted R^2, F-values, and *p*-values are based on permutation tests with 999 iterations.

Model	Predictors/effect	R^2	R^2_{adj}	F–value	*p*-value
RDA_{full}	Environment + Geography	0.676	0.514	4.1784	0.001
$pRDA_{env}$	Environment | Geography	0.243	0.169	2.5063	0.001
$pRDA_{geo}$	Geography | Environment	0.131	0.083	2.0303	0.140

DISCUSSION

Although our data fall within the broader morphological variation reported for *Juniperus sabina* in dendrological literature (Krüssmann 1972, Vidaković 1991, Farjon 2005, Idžojtić 2013, Adams 2014), direct comparisons with earlier studies remain challenging due to methodological inconsistencies – particularly in how scale leaves and shoot segments are defined and measured. As a result, traits related to vegetative morphology are difficult to compare reliably across studies, whereas cone dimensions – being less sensitive to morpho-anatomical interpretation – allow for more meaningful comparisons.

For instance, Amaral Franco (1964) and Mazur et al. (2021) reported notably smaller shoot width values (0.6–0.8 mm and 0.9 mm, respectively), both of which fall below the average observed in our populations (1.3 mm). These discrepancies likely stem from differences in sampling protocols, measurement criteria, and the type of material analysed. Mazur et al. (2021) explicitly stated that their material was dried without pressing prior to measurement, whereas our study relied on freshly collected specimens. Drying can cause shrinkage and deformation of vegetative structures, especially scale leaves and thin shoots, which likely contributed to the smaller values reported in their study. In addition, discrepancies may also arise from differences in the shoot segment selected for measurement. A similar divergence was observed in leaf counts: Mazur et al. (2021) reported approximately 18 scale leaves per 0.5 cm of shoot, while our counts reached 30 scale leaves per centimetre – equating to roughly 15 per 0.5 cm. Finally, the average length of facial scale leaves in our study was 1.6 mm, which fits well within the 1–3 mm range reported by Krüssmann (1972). He emphasized that leaf scale size varies depending on shoot type – being shorter on lateral branchlets and longer on apical axes – which further supports the consistency of our sampling, based on facial scale leaves measured on short lateral branchlets. Altogether, these comparisons highlight the importance of clearly defined sampling criteria in morphometric studies. Given the developmental plasticity and structural variability of vegetative traits in juniper species with scale leaves (Mazur et al. 2003, Douaihy et al. 2012, Boratyński et al. 2013), standardized definitions, consistent measurement protocols, and careful consideration of material type (fresh vs. dried) are essential for ensuring reproducibility and meaningful comparisons across studies.

Cone traits showed general agreement with published data (Krüssmann 1972, Vidaković 1991, Farjon 2005, Idžojtić 2013, Adams 2014), particularly with the values reported for *Juniperus sabina* in Mazur et al. (2021). In our populations, mean cone length (CL) was 6.0 mm, cone width (CW) averaged 6.1 mm, and cone thickness (CT) reached 5.8 mm. These values are slightly lower than those reported for var. *balkanensis* (CL = 6.5 mm, CW = 6.8 mm, CT = 6.0 mm), but closely resemble those recorded for var. *sabina* (CL = 6.1 mm, CW = 6.0 mm, CT = 5.3 mm), indicating partial overlap in cone morphology between the two varieties. The average number of seeds per cone in our samples was 2.1, nearly identical to the mean of 2.2 reported by Mazur et al. (2021), and within the species-level range described by Krüssmann (1–3 seeds). In our case, seed number ranged from 1 to 4, suggesting slightly broader variability. Likewise, Krüssmann (1972) noted that cone length typically falls between 5 and 7 mm, which aligns well with our observed values.

While our measurements generally fall within the ranges reported in literature (Krüssmann 1972, Vidaković 1991, Farjon 2005, Idžojtić 2013, Adams 2014, Mazur et al. 2021), the morphological distinction between *Juniperus sabina* var. *balkanensis* and var. *sabina* remains weakly defined. As emphasized by Mazur et al. (2021), most traits showed statistically significant differences between varieties, yet the overall morphological structure was only weakly expressed. This supports the interpretation of var. *balkanensis* as morphologically cryptic, with its recognition based primarily on genetic evidence (Jadwiszczak et al. 2023, 2024), particularly plastid DNA indicative of ancient hybridization events, as first described by Adams et al. (2016). Our findings reinforce this view: morphological traits in var. *balkanensis* populations do not provide clear diagnostic separation from var. *sabina* described in the literature (Adams et al. 2016). Taken together, these results highlight the limitations of morphology alone in resolving intraspecific variation of *Juniperus sabina* and underscore the need for integrative approaches that combine morphometric, ecological, and molecular data.

Sex-based differences were observed in several morphometric traits, most notably in the number and length of scale leaves. Female shrubs consistently produced more facial and lateral scale leaves per centimetre of shoot, whereas male shrubs exhibited slightly longer facial scale leaves. Epidermal thickness was also marginally greater in female shrubs across populations. Shoot width showed no variation between sexes, and none of the traits exhibited a significant population × sex interaction, indicating that sexual dimorphism was consistent across populations and not context-dependent. Nonetheless, with a sample size of 35 shrubs from only three populations, these findings

should be interpreted with caution regarding broader species-level patterns. Although female plants produced more scale leaves per centimetre of shoot, this does not necessarily imply a greater vegetative investment overall, as total shoot volume and biomass were not assessed. In gymnosperms, female plants often develop larger or more numerous leaves to support reproductive demands (Gauquelin et al. 2002, Nowak-Dyjeta et al. 2017, Stefanović et al. 2017, Vidaković et al. 2024), particularly cone maturation, which requires substantial assimilative resources. Our results partially align with this pattern, as female shrubs exhibited a higher number of scale leaves and slightly thicker epidermis. However, interpretation is further complicated by the ambiguous sexual expression of *Juniperus sabina*, a species known to exhibit both monoecious and dioecious individuals, and by the fact that male plants in this study tended to produce slightly longer facial scale leaves. Field observations revealed individuals bearing exclusively male cones, exclusively female cones, and some bearing both. All plants from which the seed cones were collected for morphometric analysis were classified as female, although some exhibited both male and female cones. This plasticity in sex expression may have influenced the final results. In this context, the reduced leaf length observed in female plants could reflect the energetic cost of producing both male and female reproductive structures. Taken together, our results suggest that sexual dimorphism in *Juniperus sabina* var. *balkanensis* is present but nuanced, shaped by reproductive demands, ecological interactions, and potentially flexible sex expression. Future studies with broader sampling and integrated physiological measurements are needed to clarify the functional significance of these patterns.

Across all populations, both our study and that by Mazur et al. (2021) revealed low to moderate coefficients of variation, indicating relatively stable trait expression and limited within-population morphological variability. Nonetheless, statistical analyses confirmed that intra-population variability was significant for all examined traits. These differences may reflect the underlying genetic heterogeneity among shrubs (Jadwiszczak et al. 2023, 2024), as well as individual-level plasticity shaped by microhabitat conditions such as soil composition, light exposure, and moisture availability (Douaihy et al. 2012, Boratyński et al. 2013, Vidaković et al. 2024). Although our study was based on morphometric data, the observed patterns of trait stability and low to moderate intra-population differentiation are broadly consistent with the genetic diversity revealed by SilicoDArT and SNP analyses (Jadwiszczak et al. 2023), as well as microsatellite data from populations from Europe and Asia (Jadwiszczak et al. 2024). This moderate variability at the intra-population level may be shaped by processes such as inbreeding, clonal propagation, and limited gene flow between fragmented populations. These factors can constrain genetic exchange and reduce overall diversity, particularly in small or geographically isolated stands.

As in the study by Mazur et al. (2021), our results confirmed that populations of *Juniperus sabina* var. *balkanensis* can be differentiated based on both vegetative and cone traits. In our dataset, statistically significant differences were observed for three out of five vegetative traits and for one out of four cone traits. Among all analysed traits, cone length proved to be the most informative for population-level differentiation. Regarding vegetative traits, the number of lateral and facial scale leaf pairs, as well as the length of facial scale leaves, showed consistent variation among populations. In contrast, shoot width and epiderma thickness did not differ significantly, suggesting that these traits may be less sensitive to local ecological variation or more developmentally constrained. Interestingly, these findings partially diverge from those reported by Mazur et al. (2021), who identified cone thickness, shoot width, and seed length as the most discriminative traits. The discrepancy between studies likely reflects differences in the sampling area. While Mazur et al. (2021) included a broader range of populations across southeastern Europe, our study was limited to three populations within the Dinaric region of Croatia.

The clear morphological differentiation of the Biokovo population from those on the Velebit Mountain, evident in both PCA and RDA analyses, highlights ecologically and geographically structured variation within *Juniperus sabina* var. *balkanensis* in the studied area. Remarkably, such divergence occurs across a relatively small geographic scale: the Biokovo Mountain lies only about 150 km in a straight line from the Velebit Mountain, yet the two ranges are separated by extensive stretches of unsuitable habitat for the studied species. This barrier likely restricts gene flow and reinforces isolation, providing a framework for understanding the observed differentiation. Our results showed that in both cases – whether vegetative organs or cones were considered – the full RDA models were significant, confirming that trait variation is best explained when environmental and spatial gradients are combined. Geographically isolated and exposed to higher solar radiation and reduced precipitation compared to northern ranges (Table 1), the Biokovo population exhibited a greater number of scale leaves and shorter cones with more seeds, whereas the Velebit populations had longer facial scale leaves in lower numbers and longer cones with fewer seeds.

These contrasting trait patterns, shaped by ecological gradients and reinforced by geographic isolation, may promote long-term divergence through local adaptation and phenotypic plasticity. Previous genetic studies have already demonstrated that *Juniperus sabina* populations are significantly differentiated and that gene flow across mountain ranges is strongly limited (Jadwiszczak et al. 2023, 2024), resulting in an isolation-by-distance pattern. Our findings of morphological divergence and geo-ecological structuring are therefore consistent with this broader genetic evidence, reinforcing the interpretation that differentiation in *Juniperus sabina* var. *balkanensis* results from the restricted gene flow imposed by mountain ranges.

CONCLUSIONS

This study provides a detailed assessment of vegetative and cone trait variation in *Juniperus sabina* var. *balkanensis* across three natural populations in the Croatian Dinaric Alps. Overall, the studied traits exhibited low to moderate variability within populations, consistent with previous genetic studies suggesting limited gene flow and clonal propagation.

Facial and lateral scale leaves differed among populations in both number and size. The Biokovo population showed the highest mean values and broader ranges for leaf scale number, whereas populations from the Velebit range (Veliki Alan and Mali Alan) were characterized by longer facial scale leaves. Shoot width and epidermal thickness remained relatively stable across sites. Within-population variability was most pronounced in leaf number and length, with individual shrubs contributing substantially to overall morphological diversity.

Cone traits exhibited the clearest and most significant differentiation in cone length, with Biokovo shrubs producing shorter cones on average, while populations from the Velebit range developed longer ones. By contrast, cone width and thickness varied predominantly at the individual level and did not show consistent spatial structuring. Seed number per cone contributed further to the observed variability: Biokovo cones, although shorter, contained more seeds, whereas Velebit cones were longer but held fewer seeds.

Sexual dimorphism was evident in several vegetative traits: female plants consistently produced more numerous and slightly thicker scale leaves, while males developed longer facial leaves. These patterns were uniform across populations, suggesting intrinsic sex-linked developmental differences rather than site-specific effects.

Multivariate analyses provided further insight into population variability. PCA highlighted the traits most responsible for population differentiation – leaf number and length among vegetative traits, and cone size and seed number among generative traits – while RDA confirmed that these differences are not random but structured by environmental and spatial gradients.

Taken together, these findings underscore the importance of variation at multiple levels – among individual shrubs within populations, across populations, and between sexes – alongside the combined influence of ecological and spatial gradients in shaping trait expression within this morphologically cryptic lineage. The observed patterns highlight the need for integrative approaches combining morphometric and ecological data to better understand the evolutionary dynamics of *Juniperus sabina* var. *balkanensis* and to inform conservation strategies for fragmented mountain shrublands.

ACKNOWLEDGMENT

This research was supported by funding from the University of Zagreb. The authors sincerely thank Marko Bukovac for his invaluable assistance in sample collection. We are also grateful to the staff of Northern Velebit National Park and Biokovo Nature Park for their kind support during fieldwork. All field activities were conducted in accordance with institutional, national, and international regulations concerning biodiversity research and sample collection. Permission to collect plant material was granted by the Ministry of Economy and Sustainable Development of the Republic of Croatia (PermitNos. UP/I 612-07/21-33/57 and UP/I-352-04/24-08/18).

REFERENCES

- Adams, R.P., 2014: Junipers of the World: The Genus *Juniperus*, 4th ed. Trafford Publishing, Bloomington, IN, USA.
- Adams, R.P., A.E. Schwarzbach, A.N. Tashev, 2016: Chloroplast capture by a new variety, *Juniperus sabina* var. *balkanensis* R.P. Adams and A.N. Tashev, from the Balkan Peninsula: A putative stabilized relictual hybrid between *J. sabina* and ancestral *J. thurifera*. Phytologia 98: 100–111.
- Adams, R.P., A. Boratyński, T. Mataraci, A.N. Tashev, A.E. Schwarzbach, 2017: Discovery of *Juniperus sabina* var. *balkanensis* R.P. Adams and A.N. Tashev in western Turkey (Anatolia). Phytologia 99: 22–31.
- Adams, R.P., A. Boratyński, K. Marcysiak, F. Roma-Marzio, L. Peruzzi, F. Bartolucci, F. Conti, T. Mataraci, A.E. Schwarzbach, A.N. Tashev, S. Siljak-Yakovlev, 2018: Discovery of *Juniperus sabina* var. *balkanensis* R.P. Adams and A.N. Tashev in Macedonia, Bosnia-Herzegovina, Croatia and Central and Southern Italy and relictual polymorphisms found in nrDNA. Phytologia 100: 117–127.
- Amaral Franco, J., 1964: *Juniperus* L. In (Tutin, T.G., V.H. Heywood, N.A. Burges, D.H. Valentine, S.M. Walters, D.A. Webb, eds.): Flora Europaea. Cambridge University Press, Cambridge, UK, Volume 1, pp. 38–39.
- Bates, D., M. Maechler, B. Bolker, S. Walker, 2025: "Fitting linear mixed-effects models using lme4." Journal of Statistical Software, 67 (1): 1–48. https://doi.org/10.18637/jss.v067.i01

- Boratyński, A., A.K. Jasińska, K. Marcysiak, M. Mazur, A.M. Romo, K. Boratyńska, K. Sobierajska, G. Iszkuło, 2019: Morphological differentiation supports the genetic pattern of the geographic structure of *Juniperus thurifera* (Cupressaceae). Plant Systematics and Evolution 305: 109–123. https://doi.org/10.1007/s00606-018-1559-1
- Douaihy, B., K. Sobierajska, A.K. Jasińska, K. Boratyńska, T. Ok, A.M. Romo, N. Machon, Y. Didukh, M. Bou Dagher-Kharrat, A. Boratyński, 2012: Morphological versus molecular markers to describe variability in *Juniperus excelsa* subsp. *excelsa* (Cupressaceae). AoB PLANTS 2012: pls013. https://doi.org/10.1093/aobpla/pls013
- Farhat, P., S. Siljak-Yakovlev, R.P. Adams, M. Bou Dagher Kharrat, T. Robert, 2019: Genome size variation and polyploidy in the geographical range of *Juniperus sabina* L. (Cupressaceae). Botany Letters 166 (2): 134–143. https://doi.org/10.1080/23818107.2019.1613262
- Farjon, A., 2005: *Juniperus*. In (Farjon, A., ed.): A Monograph of Cupressaceae and *Sciadopitys*. Royal Botanic Gardens, Kew, UK, pp. 228–400.
- Fick, S.E., R.J. Hijmans, 2017: WorldClim 2: New 1-km spatial resolution climate surfaces for global land areas. International Journal of Climatology 37 (12): 4302–4315. https://doi.org/10.1002/joc.5086
- Fox, J., S. Weisberg, 2019: An R Companion to Applied Regression. Third edition. Sage, Thousand Oaks CA. https://www.john-fox.ca/Companion/
- Gauquelin, T., V. Bertaudière-Montès, W. Badri, N. Montès, 2002: Sex ratio and sexual dimorphism in mountain dioecious thuriferous juniper (*Juniperus thurifera* L., Cupressaceae). Botanical Journal of the Linnean Society 138 (2): 237–244. https://doi.org/10.1046/j.1095-8339.2002.138002237.x
- Idžojtić, M., 2013: Dendrologija: cvijet, češer, plod, sjeme. Sveučilište u Zagrebu, Fakultet šumarstva i drvne tehnologije, Zagreb.
- Jadwiszczak, K.A., M. Mazur, A. Bona, K. Marcysiak, A. Boratyński, 2023: Three systems of molecular markers reveal genetic differences between varieties *sabina* and *balkanensis* in the *Juniperus sabina* L. range. Annals of Forest Science 80 (45). https://doi.org/10.1186/s13595-023-01211-w
- Jadwiszczak, K.A., M. Mazur, A. Bona, K. Marcysiak, A. Boratyński, 2024: Soil requirements, genetic diversity and population history of the *Juniperus sabina* L. varieties in Europe and Asia. Forests 15 (5): 866. https://doi.org/10.3390/f15050866
- Kassambara, A., F. Mundt, 2020: factoextra: Extract and Visualize the Results of Multivariate Data Analyses. R package version 1.0.7.999. https://github.com/kassambara/factoextra
- Krüssmann, G., 1972: Handbuch der Nadelgehölze. Paul Parey Verlag. Berlin.
- Lê, S., J. Josse, F. Husson, 2008: FactoMineR: A Package for Multivariate Analysis. Journal of Statistical Software 25 (1): 1–18. https://doi.org/10.18637/jss.v025.i01
- Mao, K., G. Hao, J. Liu, R.P. Adams, R.I. Milne, 2010: Diversification and biogeography of *Juniperus* (Cupressaceae): variable diversification rates and multiple intercontinental dispersals. New Phytologist 188: 254–272. https://doi.org/10.1111/j.1469-8137.2010.03351.x
- Mazur, M., K. Boratyńska, K. Marcysiak, D. Gómez, D. Tomaszewski, Y.P. Didukh, A. Boratyński, 2003: Morphological variability of *Juniperus phoenicea* (Cupressaceae) from three distant localities on Iberian Peninsula. Acta Societatis Botanicorum Poloniae 72 (1): 27–33. https://doi.org/10.5586/asbp.2003.009
- Mazur, M., A. Boratyński, K. Boratyńska, K. Marcysiak, 2021: Weak geographical structure of *Juniperus sabina* (Cupressaceae) morphology despite its discontinuous range and genetic differentiation. Diversity 13 (10): 470. https://doi.org/10.3390/d13100470
- Nowak-Dyjeta, K., M.J. Giertych, P. Thomas, G. Iszkuło, 2017: Males and females of *Juniperus communis* L. and *Taxus baccata* L. show different seasonal patterns of nitrogen and carbon content in needles. Acta Physiologiae Plantarum 39 (8): 191. https://doi.org/10.1007/s11738-017-2489-3
- Oksanen, J., F.G. Blanchet, M. Friendly, R. Kindt, P. Legendre, D. McGlinn, P.R. Minchin, R.B. O'Hara, G.L. Simpson, P. Solymos, M.H.H. Stevens, E. Szoecs, H. Wagner, 2022: vegan: Community Ecology Package. R package version 2.6-4. https://CRAN.R-project.org/package=vegan
- Preciv™ Capture, 2021: PRECiV Advanced Imaging Analysis. Version 1.2. Evident. Tokyo. https://evidentscientific.com/en/products/software/preciv
- R Core Team, 2025: R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. https://www.r-project.org/
- Royal Botanic Gardens, Kew, 2023: *Juniperus sabina* L. In: Plants of the World Online. https://powo.science.kew.org/taxon/urn:lsid:ipni.org:names:30166980-2
- Slowikowski, K., 2024: ggrepel: Automatically Position Non-Overlapping Text Labels with 'ggplot2'. R package version 0.9.6. https://CRAN.R-project.org/package=ggrepel
- Stefanović, M., B. Nikolić, R. Matić, Z. Popović, V. Vidaković, S. Bojović, 2017: Exploration of sexual dimorphism of *Taxus baccata* L. needles in natural populations. Trees 31: 1697–1710. https://doi.org/10.1007/s00468-017-1579-6
- Topić, J., J. Vukelić, 2009: Priručnik za određivanje kopnenih staništa u Hrvatskoj prema Direktivi o staništima EU. Državni zavod za zaštitu prirode. Zagreb.
- Vidaković, A., Z. Šatović, K. Tumpa, M. Idžojtić, A. Barišić, I. Poljak, 2024: Secondary sexual dimorphism and morphological diversity in two allopatric juniper species: *Juniperus oxycedrus* and *J. deltoides*. Acta Botanica Croatica 83 (1): 14–25. https://doi.org/10.37427/botcro-2024-007
- Vidaković, M., 1991: Conifers: Morphology and Variation. Grafički zavod Hrvatske. Zagreb.
- Wickham, H., 2016: ggplot2: Elegant graphics for data analysis. Springer-Verlag, New York. https://ggplot2.tidyverse.org
- Xiao, N., 2024: ggsci: Scientific Journal and Sci-Fi Themed Color Palettes for 'ggplot2'. R package version 3.2.0. https://CRAN.R-project.org/package=ggsci

https://doi.org/10.31298/sl.149.11-12.3

Izvorni znanstveni članci – Original scientific papers
Šumarski list, 11-12 (2025): 531-544

CONE AND SEED VARIABILITY IN SERBIAN SPRUCE – INDICATORS OF POPULATION ENDANGERMENT

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SUMMARY

Serbian spruce (*Picea omorika* (Pančić) Purk., Pinaceae) is a tertiary relict and one of the rarest, most endangered, and protected conifer species in Europe. Alarmingly, many studies report a continuous decline in its population and vitality. In response to this concerning trend, the present research aims to better understand the reproductive potential of this species by analysing cone and seed characteristics, as well as intra- and inter-population variability — the critical factors for designing effective *in situ* and *ex situ* conservation strategies. To achieve this, cones were collected during the 2022/23 season (autumn/spring) from 111 trees across seven natural populations and one urban population in Bosnia and Herzegovina. Immediately after collection, cones were measured and processed, seeds were extracted, and germination tests were conducted in April–May 2023. The analysis revealed significant differences among trees and populations for all cone traits. Notably, the level of intra-population variability observed closely resembles the patterns previously identified in genetic studies of the same populations, suggesting a consistent underlying diversity structure. However, the overall germination results point to very low seed viability, 57.03% on average, with 26.85% of seeds being empty. Population-level differences were pronounced: germination rates ranged from 20.40% to 81.14%, while the proportion of empty seeds ranged from 8.10% to 59.60%. Overall, our results suggest that small and endangered populations are particularly vulnerable, producing smaller cones with a higher proportion of empty seeds and significantly lower germination success. This highlights an urgent need for conservation action — to protect the species and support natural regeneration *in situ*, and to establish *ex situ* plantations beyond its natural range.

KEY WORDS: cone morphology, endangered populations, genetic diversity, *in situ* and *ex situ* conservation, population differentiation, reproductive biology, seed viability

INTRODUCTION

The survival, or more precisely, the regeneration of a plant species involves seed production, dispersal, germination, and the successful growth of seedlings. Each species has its own unique germination requirements, which can be seen as adaptations for maximizing survival in an unstable and unpredictable environment (Fenner 1985, Iralu et al. 2019). Seed germination and seedling development are critical phases in the life cycle, shaping population dynamics and ultimately influencing the development, structure, and survival of ecosystems (Chen and Xie 2007, Baeten et al. 2009, Grossnickle and Ivetić 2017). These phases are marked by exceptionally high mortality rates and intense natural selection (Leck et al. 2008, Grossnickle 2018). Consequently, the seedling stage is often considered a "bottleneck" in the life history of a species (Kolb and Barsch 2010, Grossnickle 2016).

A significant number of plant species worldwide are becoming endangered because processes such as seed

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dispersal, germination, and seedling development and survival are increasingly disrupted (Colin and Linda 2002, Gulias et al. 2004). The Intergovernmental Panel on Climate Change (IPCC) estimates that roughly 20–30% of vascular plants may face extinction with a global temperature rise of 2–3°C (Parry et al. 2007). Even small losses in biodiversity can result in profound changes in ecosystem services (Seppälä et al. 2009). Studying the factors behind population declines in endangered plant species, their ecological adaptability (Tumpa et al. 2022), and their mechanisms to mitigate threats has become essential. This knowledge lays the foundation for designing effective strategies to protect their genetic diversity and maintain viable population sizes, making it a priority in global biodiversity conservation efforts (Fernández and Tapias 2022, Xu et al. 2022, Xu and Zang 2023).

Seedling emergence, survival, and establishment are strongly influenced by habitat conditions (Bazzaz 1991, Mataruga et al. 2012, Tumpa et al. 2021), which makes these factors critical for understanding population dynamics and the resilience of plant species. Species with small populations and unique genetic characteristics (Mataruga et al. 2020, Aleksić et al. 2022) are especially vulnerable to the challenges posed by inbreeding depression and various demographic and ecological pressures (Hensen and Wesche 2006). Understanding these influences is crucial, as contemporary ecological factors affecting population growth in endangered plant species remain poorly understood, and there is limited knowledge on effective management strategies. Establishing scientific guidelines for conservation requires a focus on traits like seed germination and seedling development that limit population recovery, even at critically low sizes (Yates and Broadhurst 2002). One notable example of such vulnerability is Serbian spruce (*Picea omorika* (Pančić) Purk., Pinaceae), a species with a limited population size and unique genetic makeup, which faces significant threats due to these challenges (Pintarić 1969, Dinić 1990, Mataruga et al. 2020, Aleksić et al. 2022).

Serbian spruce is a tertiary relict found only in the mid-course of the Drina River canyon, within a narrow range from 19°09' – 44°07'N (Tisovljak site) to 19°46' – 43°20'N (Mileševa site). All sites are located at altitudes ranging from 750 to 1,550 meters above sea level on very steep, north-facing slopes (Mataruga and Milanović 2020). This species is categorized as endangered by the IUCN (Mataruga et al. 2011) and is protected by the governments of Bosnia and Herzegovina and the Republic of Serbia. The surviving populations persist in highly fragmented habitats in minimal numbers; often only a few mature trees survive, usually several dozen, and rarely up to about a thousand. The problem of natural regeneration in these populations is recognized, with young seedlings being almost non-existent unless a catastrophic event such as a fire, avalanche, or landslide occurs. Genetic and developmental characteristics have been studied to uncover the causes of its endangerment (Aleksić and Geburek 2010, Mataruga et al. 2020), with slow natural regeneration identified as the primary factor limiting its survival (Mataruga and Milanović 2020). The species' seed germination and seedling formation traits remain unclear in terms of processes related to regeneration, stability, migration, and distribution. In addition, little attention has been given to the quality of seeds or the effects of different treatments on germination of this species (Cvjetković 2011).

To date, extensive research has been conducted on natural populations of Serbian spruce, covering aspects such as genetic diversity (Ballian et al. 2006, Nasri et al. 2008, Aleksić and Geburek 2010, Aleksić et al. 2017, Mataruga et al. 2020), morpho-anatomical variability of needles (Radovanović et al. 2014, Nikolić et al. 2015, Popović et al. 2020), and needles' chemical composition (Nikolić et al. 2009, 2025). However, studies on population variability based on cone and seed morphology remain scarce (Isajev 1987), as do investigations into seed germination dynamics. Our aim was to address these knowledge gaps by analysing population variability through cone and seed morphology, while also examining seed germination potential in the context of factors affecting population persistence. Understanding these factors is essential for developing effective conservation strategies for this critically endangered species.

MATERIALS AND METHODS

Studied species

Serbian spruce is a medium-sized evergreen conifer, reaching heights of 20 to 40 meters. It is distinguished by its remarkably slender, spindle-shaped form, and narrow pyramidal crow (Vidaković 1982). The bark is thin, reddish-brown, and scaly, gradually fissuring with age. Its needles measure 7–20 mm in length and approximately 2 mm in width (Nikolić et al. 2024), dark green on the upper side, with two distinct white stomatal bands on the underside. The needle tips range from rounded to pointed, and they are elliptical, triangular or rhomboidal in cross-section (Radovanović et al. 2014, Nikolić et al. 2015), attached singly to small, persistent peg-like structures (pulvini or sterigmata) on the branches. Male cones are small and reddish, while female cones are positioned higher in the crown and exhibit a similar reddish hue (Krüssmann 1972). Flowering occurs from April to June, with wind pollination ensuring reproductive success. The seed cones are elongated, measuring 2–6 cm in

length and 1–2 cm in width (Idžojtić 2019). Initially deep purple to bluish-brown, they mature to dark brown with a subtle bluish tint in autumn of the first year. Seed dispersal relies on wind, facilitated by light, ovate seeds with an 8 mm long wing. Serbian spruce thrives in diverse habitats and is highly tolerant of air pollution, contributing to its widespread cultivation in botanical gardens and arboretums worldwide. However, despite these adaptations, it is gradually disappearing from its natural habitats due to poor natural regeneration, making conservation efforts crucial for its survival.

Study area

In 2022, an abundant yield of Serbian spruce cones was observed in a significant number of natural populations. The cones were collected in the autumn of 2022 by climbing trees, ensuring the identification of each maternal (test) tree – half-sib lines. All cones were collected from a total of 111 trees across seven natural and one urban population (Figure 1, Table 1). For each tree, coordinates were recorded, basic dendrometric data were taken (diameter (DBH) and height (TH)), and the trees were marked in the field. Out of the 26 described populations in Bosnia and Herzegovina (Mataruga and Milanović 2020), seven spatially isolated natural populations were included (Table 1). The most endangered and habitat-specific populations with cone yield were chosen following previous recommendations (Mataruga and Milanović 2020). Habitat conditions in all sampled populations are similar. The soil is very shallow and of the colluvium type. Detailed climatic data for the study sites are provided by Mataruga and Milanović (2024). In addition to cones collected from natural populations, cones were also collected from mature trees in the urban area of the city of Banja Luka in early spring 2023.

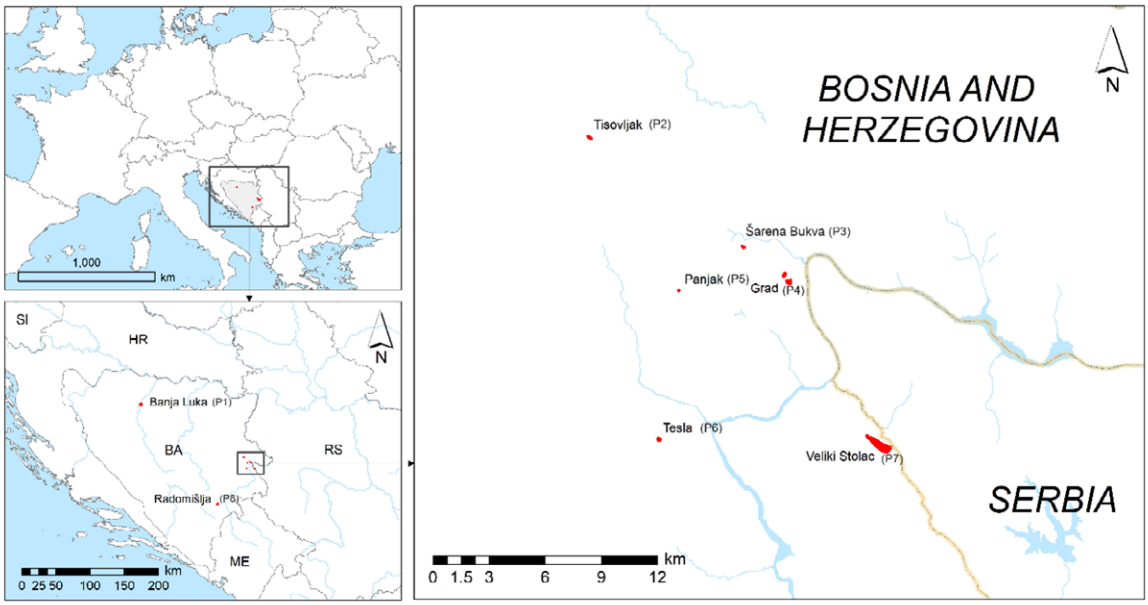

Figure 1 Spatial distribution of Serbian spruce populations where cone samples were collected.

Table 1 Basic characteristics of studied populations: population ID, population name, longitude (E), latitude (N), altitude (m), area (ha), estimated number of mature trees (EN), offspring (OF), number of trees from which seeds were collected (NT), multivariate diversity index (MDI).

Population ID	Population name	Longitude (E)	Latitude (N)	Altitude (m)	Area (ha)	Estimated number of mature trees (EN)	Offspring (OF)	Number of trees from which seeds were collected (NT)	Multivariate diversity index (MDI)
P1	Banja Luka	17.198876	44.764852	160–190	-	-	None	24	1.497
P2	Tisovljak	19.091117	44.072907	980–1080	2.6	100	Rare	17	1.313
P3	Šarena Bukva	19.192886	44.019238	1000–1090	1.0	150	Rare	10	1.515
P4	Grad	19.219963	44.005645	1100–1220	4.4	300	Rare	11	1.540
P5	Panjak	19.149446	43.998802	1270–1330	0.6	30	None	9	0.617
P6	Tesla	19.134806	43.927498	970–1110	2.6	50	Sporadic	11	1.366
P7	Veliki Stolac	19.282496	43.922926	1050–1580	43.8	1000	Sporadic	21	1.076
P8	Radomišlja	18.606057	43.459431	850–1395	44.1	2000	Sporadic	8	1.324

Morphometric analysis and germination tests

Immediately after collection, the total mass of all freshly collected cones from each tree was measured (TMFC). In addition, mass (CM), length (CL), and width (CW) at the widest part were recorded for 12 randomly selected cones from each tree. The cones were then placed in a BCC drying chamber at ±48°C for 72 hours (Rietz and Torgeson 1937, Aldhous 1972). After drying, the seeds were extracted from the cones, and both the dry mass of the cones (TMDC) and the dry mass of the seeds with (SMW) and without wings (SMNW) were measured.

The cone moisture content (CMC) was calculated using the formula:

$$\mathrm{CMC}\ (\%) = \frac{(\mathrm{TMFC} - \mathrm{TMDC}) \cdot 100}{\mathrm{TMFC}}$$

The extraction factor or mass of seeds obtained from the cones is presented in percentages (SMC) using the formula:

$$\mathrm{SMC} = \frac{\mathrm{SMW} \cdot 100}{\mathrm{TMDC}}$$

After manual seed deburring, impurities were removed using the BCC gravity separator. To determine the absolute mass (mass of 1000 seeds) and the number of seeds per kilogram, four sets of 100 seeds were weighted for each tree. Absolute mass and the number of seeds per kilogram were analysed using samples from five randomly selected trees from each originating natural population, totalling 35 test trees. The seeds were then stored in a refrigerator at 4±1°C.

Between 11 April 11 to 2 May 2023, the seeds were placed on a germination table, known as the "Copenhagen table" or "Jacobsen table" (Germinationtable GR10), which maintains a constant temperature and precisely controlled moisture levels, ensuring uniform treatment across all seed samples. Four sets of 100 seeds were placed on filter paper in continuous contact with water at a temperature of 21°C. A total of 101 trees out of 111 were tested, as some trees from which the cones were collected did not yield enough seeds for testing. The number of normally germinated seeds was recorded on days 7, 14, and 21 from the start of the test. On the final day, the number of normally germinated seeds, full but ungerminated seeds, and empty seeds were documented. Seeds were considered normally germinated when the root had broken through the seed coat and grown to at least half the seed's length.

Four parameters were calculated: germination percentage (GP), germination energy (GE), the number of empty seeds (ES), and the number of full but ungerminated seeds (FS) as follows:

- GP = GP_21 (%) = (total number of germinated seeds on the 21st day × 100) / total number of seeds set for germination
- GE = GP_7 (%) = (number of seeds germinated on the 7th day × 100) / total number of seeds set for germination
- ES (%) = (total number of empty seeds × 100) / total number of seeds set for germination
- FS (%) = (number of full but ungerminated seeds × 100) / total number of seeds set for germination

Statistical analysis

Descriptive statistics were performed using Statistica 7.0 (StatSoft Inc. 2004). Analysis of variance (ANOVA) and Duncan's test were employed to determine the significance of differences, with significance levels set at $p < 0.01$. The Statistica program was also used for correlation analysis to assess the interdependence of seed, cone and tree traits. Principal Component Analysis (PCA) was conducted to reveal the interactions between the analysed variables and to reduce them to a smaller number of factors. A biplot was constructed using two principal components to illustrate analysed individuals and traits. To quantify variability within populations, the multivariate diversity index (MDI) was calculated for each studied population (Poljak et. 2024, Vidaković et al. 2024).

RESULTS

Basic characteristics of the studied trees

The eight studied populations—P1 (Banja Luka), P2 (Tisovljak), P3 (Šarena Bukva), P4 (Grad), P5 (Panjak), P6 (Tesla), P7 (Veliki Stolac) and P8 (Radomišlje)—yielded a total of 111 sampled trees (Table 2), with per-population sample sizes ranging from eight trees in Radomišlje (P8) to 24 in Banja Luka (P1). Across all sites, mean tree height was 16.54 m, with population means ranging from 10.67 m in Banja Luka (P1) to 24.15 m in Tisovljak (P2); individual heights ranged from 7.00 to 32.60 m. Diameter at breast height (DBH) averaged 21.75 cm, population means varied from 18.03 cm in Šarena Bukva (P3) to 26.40 cm in Tisovljak (P2), and single-tree DBH values lay between 12.10 and 41.72 cm. These results highlight substantial variability among the eight populations.

Mass of cones and seeds, cone moisture content and the percentage of seeds per cone

On average, 840.34 grams of cones (747.03 grams in dry weight) were collected from a single tree, yielding 28.34 grams of seeds with wings and 14.06 grams without wings (Table 2). The smallest quantity of cones was collected from the tree Veliki Stolac_16 (P7), amounting to 68.18 grams in fresh weight (59.18 grams in dry weight), while

the largest collection came from the tree Radomišlja_3 (P8), totalling 1,986.54 grams in fresh weight (1,741.54 grams in dry weight). The highest seed yield was recorded from the tree Tisovljak_1 (P2), producing 82.08 grams of seeds with wings (48.22 grams without wings), followed closely by the tree Radomišlja_3 (P8) which yielded 69.32 grams of seeds with wings (50.21 grams without wings).

The average moisture content of cones (CMC) was 11.12%, ranging from 7.31% in the Banja Luka population (P1) to 14.07% in the Radomišlje population (P8). Since cones from Radomišlje (P8) were collected in late autumn and those from Banja Luka (P1) in early spring, it is evident that the time of cone collection, and the prevailing weather conditions are a primary determinant of cone moisture content.

The percentage of seeds per cone (SMC) ranged from 2.53% (P6 – Tesla) and 2.73% (P5 – Panjak) to 5.26% in the Veliki Stolac (P7) population. In contrast to cone moisture content, seed yield from cones appears to be more dependent on the specific population. Notably, Tesla and Panjak—both characterized by a limited number of trees and considered highly endangered—exhibited the lowest seed yield values.

On average, the smallest and lightest seeds were collected from the Tesla (P6) and Panjak (P5) populations, with more than 600,000 seeds per kilogram. In contrast, the largest seeds were found in the Veliki Stolac (P7) population (378,000 seeds per kilogram), while the Grad (P4), Šarena Bukva (P3), Radomišlja (P8), Tisovljak (P2) and Banja Luka (P1) populations had slightly over 400,000 to 430,000 seeds per kilogram (Table 2). The highest seed production per tree was recorded in the Radomišlja (P8) population with approximately 21,000 seeds. This number was calculated by multiplying the absolute mass of a single seed by the total seed mass obtained from the tree (21,877 = 435,714 × 0.05021). It is important to note that a significant number of trees did not yield any seeds after cone extraction, as their cones remained closed even after several days of drying. This was observed in multiple trees from the Tesla (P6) and Panjak (P5) populations, such as Tesla_1, 7, 8, 9, 10; Panjak_1, 5, 6, 9. In addition, a higher number of seeds per kilogram does not necessarily indicate smaller seeds, as large proportion of empty seeds was present. Although seed size was not directly measured, populations with a higher seed count per kilogram generally had smaller seeds, based on observations during seed processing.

Table 2 Basic characteristics of the studied trees, mass of collected cones and seeds, cone moisture content, percentage of seeds per cone and seed count per kilogram.

Population ID	Population	Number of trees	Descriptive parameters	Trees from which seeds were collected		Mass of cones (g)		Mass of seeds (g)		Cone moisture content (%)	Percentage of seeds per cone (%)	Number of seeds per kilogram
				Height (m)	Diameter at breast height (cm)	After collection	After drying	With wings	Without wings			
P1	Banja Luka	24	Average	10.67	18.31	927.42	858.58	28.78	8.77	7.31	3.33	436,820
			Min	7.00	13.06	228.54	216.54	5.86	2.76	3.94	2.26	360,358
			Max	12.50	24.52	1,670.54	1,546.54	68.72	22.74	9.47	4.56	620,320
P2	Tisovljak	17	Average	24.15	26.40	1113.71	981.18	46.21	22.14	11.72	4.69	433,034
			Min	17.40	16.88	394.18	339.18	11.22	6.60	5.42	2.73	322,581
			Max	30.20	39.81	1,933.18	1,560.18	82.08	48.22	19.29	6.61	555,556
P3	Šarena Bukva	10	Average	12.93	18.03	887.88	775.38	27.52	12.52	13.16	3.82	406,722
			Min	10.00	12.10	305.18	267.18	9.30	3.86	8.24	2.60	294,118
			Max	16.70	21.97	1,894.18	1,738.18	45.22	24.04	22.27	5.84	588,235
P4	Grad	11	Average	12.53	20.76	752.54	658.45	31.69	19.77	12.40	4.88	407,576
			Min	9.70	15.92	278.18	239.18	10.26	6.34	9.74	3.45	333,333
			Max	17.30	27.71	1,822.18	1,608.18	72.12	45.02	15.13	6.29	500,000
P5	Panjak	9	Average	15.96	21.76	467.51	419.62	6.65	3.51	9.94	2.73	600,446
			Min	11.30	15.92	179.18	165.18	0.00	0.00	7.81	1.33	437,500
			Max	25.80	40.45	843.18	767.18	19.46	13.80	14.56	5.62	714,286
P6	Tesla	11	Average	19.24	24.61	814.36	724.00	11.93	4.62	10.60	2.53	621,947
			Min	14.90	15.92	151.18	137.18	0.00	0.00	9.26	1.47	384,615
			Max	32.60	41.72	1,723.18	1,512.18	44.11	13.84	12.42	3.62	833,333
P7	Veliki Stolac	21	Average	19.30	22.40	596.99	519.51	27.83	17.11	13.00	5.26	378,716
			Min	14.20	13.38	68.18	59.18	2.65	1.22	7.05	3.05	277,778
			Max	26.20	29.94	950.18	845.18	52.76	32.48	18.58	6.63	568,182
P8	Radomišlje	8	Average	21.50	25.00	1,153.42	998.42	33.75	23.61	14.07	3.38	435,714
			Min	19.90	20.06	300.54	276.54	8.96	5.10	7.79	1.70	250,000
			Max	23.10	29.94	1,986.54	1,741.54	69.32	50.21	28.37	5.13	714,286
Total sample		111	Average	16.54	21.75	840.34	747.03	28.34	14.06	11.12	4.09	465,122

Morphometric traits of cones

The results show considerable variability in cone traits among populations, with significant differences in mass (CM), length (CL), and width (CW). The Grad (P4) population had the highest average cone mass (5.27 g), while Panjak (P5) and Tesla (P6) had the smallest (2.61 g and 2.86 g, respectively), whereas Banja Luka (P1) exhibited a relatively high cone mass (4.89 g). In terms of length, Banja Luka (P1) stood out with the longest cones (46.90 mm), while Panjak (P5) and Tesla (P6) had the shortest cones, measuring around 30 mm. Regarding cone width, Radomišlja (P8) recorded the largest values (17.80 mm), closely followed by P1 – Banja Luka (17.13 mm), whereas Panjak (P5) had the smallest width (13.75 mm). Statistical analysis confirmed highly significant differences among populations ($p < 0.001$ for all traits), indicating strong population-level variability, likely influenced by environmental or genetic factors.

Table 3 Mean values and standard deviation for cone traits. Values are represented as mean ± standard deviation. Duncan test results are shown as homogenous groups – same letters above the mean. The last row presents the *F* value from the analysis of variance and the *p*-value of probability.

Population ID	Population	Cone mass (g)	Cone length (mm)	Cone width (mm)
P1	Banja Luka	4.89c±1.83	46.90e±7.19	17.13e±2.15
P2	Tisovljak	4.38b±2.68	37.97b±4.62	15.98c±1.33
P3	Šarena Bukva	4.60c±2.01	38.50b±6.02	16.15c±2.07
P4	Grad	5.27d±1.54	39.96c±5.98	16.58d±1.41
P5	Panjak	2.61a±0.98	29.78a±5.56	13.75a±1.60
P6	Tesla	2.86a±1.21	30.72a±6.10	14.25b±1.42
P7	Veliki Stolac	4.72c±1.32	38.45b±4.27	16.10c±1.46
P8	Radomišlja	4.82c±1.20	43.38d±5.01	17.80f±1.48
	All populations	4.37±1.68	39.26±7.81	16.10±2.01
	F_{pop}, p_{pop}:	58.12, $p<0.001$	169.01, $p<0.001$	83.97, $p<0.001$

Germination energy and germination rate

The germination analysis revealed significant variation in rates and energy levels across different Serbian spruce populations. The Tesla (P6) and Panjak (P5) populations exhibited lower germination rates and energy levels, whereas the Veliki Stolac (P7) population demonstrated the highest values in both parameters. Notably, the Banja Luka (P1) population showed reduced germination rates compared to the others. Analysis of variance, supported by Duncan's test, confirmed significant differences among the populations, classifying them into four distinct homogeneous groups (as shown in Figure 2).

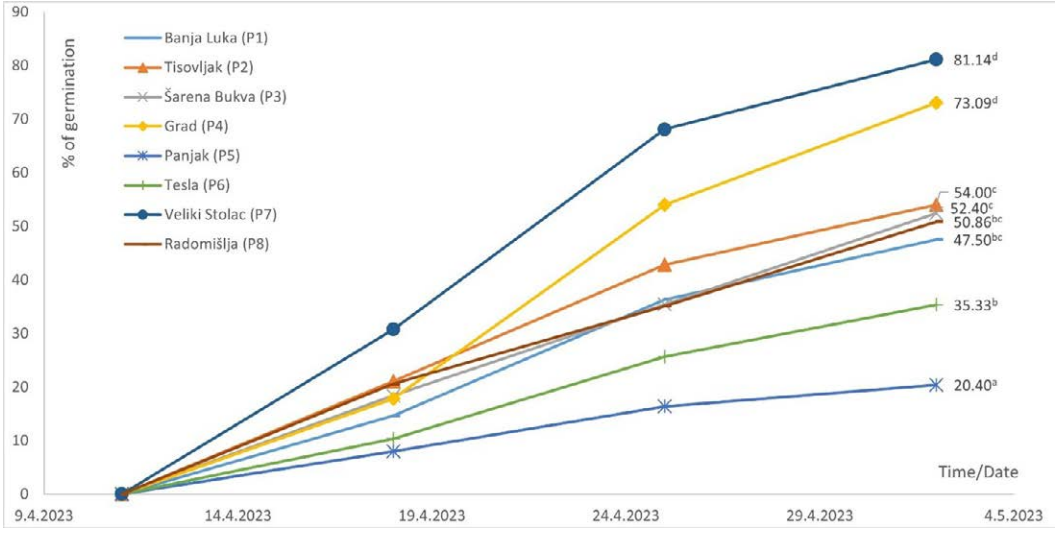

Figure 2 Seed germination dynamics across tested populations (%). Duncan's test results indicate homogenous groups, represented by letters above the germinations values.

The lower germination rates observed in the Tesla (P6) and Panjak (P5) populations can be attributed to a higher percentage of empty seeds (ES). However, differences in the number of full but ungerminated seeds (FS) were relatively small across all populations, averaging 16.12% (Figure 3). Additionally, these populations contain fewer mature trees compared to others (see Table 1). Duncan's test confirmed significant differences, which align with the observed germination rate groupings.

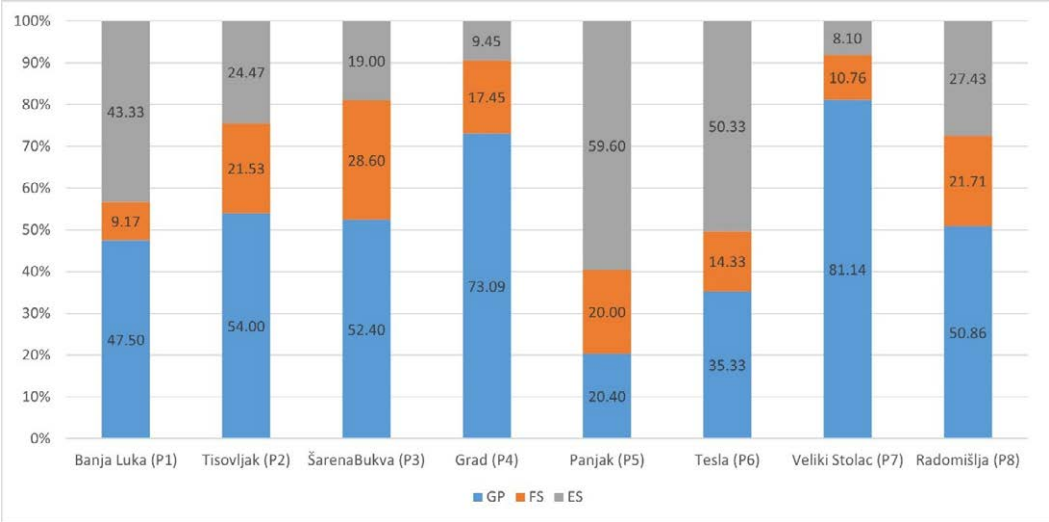

Figure 3 The percentage of germinated seeds (GP), full but ungerminated seeds (FS), and empty seeds (ES).

Correlation analysis

Table 4 shows the results of the correlation analysis. First, germination percentages at 7, 14 and 21 days (GP_7, GP_14, GP_21) are all strongly positively correlated (r = 0.701–0.922, $p < 0.01$), while the proportion of empty seeds (ES) is strongly negatively correlated with those same germination metrics (r = -0.610 to -0.863, $p < 0.01$). The percent of full but ungerminated seeds (FS) shows a low negative correlation with GP_7 (r = -0.224, $p < 0.05$) and slightly stronger negative correlation with later germination GP_14 (r = -0.366, $p < 0.01$), GP_21(r = -0.333, $p < 0.01$). Notably, seed germination was found to be independent of cone length and width.

Total mass of fresh (TMFC) and dry (TMDC) cones are essentially redundant (r = 0.996, $p < 0.01$), as are seed mass with wings (SMW) and without wings (SMNW) (r = 0.904, $p < 0.01$). These seed weight traits correlate positively with total mass of fresh (TMFC vs. SMW, r = 0.793, $p < 0.01$; TMFC vs. SMNW, r = 0.645, $p < 0.01$) and dry cones (TMDC vs. SMW, r = 0.791, $p < 0.01$; TMDC vs. SMNW, r = 0.630, $p < 0.01$), as well as with the percent of seeds per cone (SMC) (r ≈ 0.60, $p < 0.01$), and moderately with cone size parameters – mass (CM), length (CL), and width (CW) (r = 0.386–0.473, $p < 0.01$). Cone length (CL) and width (CW) are likewise highly positively correlated (r = 0.834, $p < 0.01$), and both scale closely with cone mass (CM) (r = 0.842 and r = 0.843, respectively, $p < 0.01$). Additionally, these three cone traits (CL, CW, CM) were moderately correlated with total mass of fresh (TMFC) and dry (TMDC) cones (r = 0.40–0.47, $p < 0.01$).

Cone moisture content (CMC) exhibited only a few statistically significant and weak correlations, namely, with the percent of full but ungerminated seeds (FS; r = 0.243, $p < 0.05$) and the percent of empty seeds (ES; r = –0.295, $p < 0.01$). CMC also showed a positive correlation with total cone mass (CM; r = 0.228, $p < 0.05$) and tree height (TH; r = 0.294, $p < 0.01$), while remaining uncorrelated with germination rates (GP_7, GP_14, GP_21), seed weights (SMW, SMNW), and most cone size attributes (TMFC, TMDC, CL, CW).

Tree size metrics—height (TH) and diameter at breast height (DBH)—are themselves very strongly correlated (r = 0.796, $p < 0.01$), but generally display only weak associations with seed and cone traits. Tree height (TH) showed low but statistically significant correlations with seed mass with wings (SMW; r = 0.241, $p < 0.05$), seed mass without wings (SMNW; r = 0.296, $p < 0.01$), cone moisture content (CMC; r = 0.294, $p < 0.01$), the percentage of seeds per cone (SMC; r = 0.201, $p < 0.05$), cone mass (CM; r = –0.199, $p < 0.05$), cone length (CL; r = –0.304, $p < 0.01$), and early germination at 7 days (GP_7; r = 0.217, $p < 0.05$). Similarly, DBH exhibited weak but statistically significant correlations with cone fresh weight (TMFC; r = 0.293, $p < 0.01$), dry weight (TMDC; r = 0.272, $p < 0.01$), seed mass with wings (SMW; r = 0.230, $p < 0.05$), and seed mass without wings (SMNW; r = 0.212, $p < 0.05$). No meaningful correlations were observed between DBH and germination rates (GP_7–GP_21), cone moisture content (CMC), seed output (SMC), or cone size dimensions (CM, CL, CW). Overall, all associations for TH and DBH fell within the low correlation range (|r| ≈ 0.20–0.30).

Table 4 Pearson's correlation coefficients between seed, cone and tree traits. Analysed traits: GP_7 – % of germinated seeds on day 7; GP_14 – % of germinated seeds on day 14; GP_21 – % of germinated seeds on day 21; FS – % of full but ungerminated seeds; ES – % of empty seeds; TMFC – total fresh cone mass per tree; TMDC – total dry cone mass per tree; SMW – seed mass with wings; SMNW – seed mass without wings, CMC – cone moisture content; SMC – % of seeds per cone; CM – cone mass; CL – cone length; CW – cone width; TH – tree height; DBH – diameter at breast height. Significant correlation values are marked in red.

Trait	GP_7	GP_14	GP_21	FS	ES	TMFC	TMDC	SMW	SMNW	CMC	SMC	CM	CL	CW	TH
GP_14	0.774**														
GP_21	0.701**	0.922**													
FS	-0.224*	-0.366**	-0.333**												
ES	-0.610**	-0.765**	-0.863**	-0.188											
TMFC	-0.080	-0.186	-0.139	0.039	0.123										
TMDC	-0.086	-0.184	-0.145	0.018	0.141	0.996**									
SMW	0.144	0.085	0.124	0.079	-0.171	0.793**	0.791**								
SMNW	0.251*	0.212*	0.266**	0.121	-0.341**	0.645**	0.630**	0.904**							
CMC	0.154	0.066	0.160	0.243*	-0.295**	-0.008	-0.085	0.000	0.135						
SMC	0.456**	0.523**	0.523**	0.050	-0.569**	0.039	0.032	0.567**	0.598**	0.135					
CM	-0.061	0.081	0.204*	-0.141	-0.135	0.399**	0.386**	0.467**	0.440**	0.228*	0.333**				
CL	-0.184	-0.104	-0.038	-0.183	0.135	0.466**	0.473**	0.484**	0.354**	-0.035	0.294**	0.842**			
CW	-0.157	-0.039	0.056	-0.036	-0.039	0.403**	0.404**	0.455**	0.403**	0.041	0.306**	0.843**	0.834**		
TH	0.217*	0.085	0.026	0.165	-0.114	0.162	0.137	0.241*	0.296**	0.294**	0.201*	-0.199*	-0.304**	-0.143	
DBH	-0.017	-0.093	-0.124	0.132	0.058	0.293**	0.272**	0.230*	0.212*	0.180	0.052	-0.114	-0.133	-0.020	0.796**

**Correlation is significant at the 0.01 level *Correlation is significant at the 0.05 level

Principal component analysis (PCA)

This analysis provides a comprehensive overview of the grouping and dispersion patterns among populations based on 16 studied seed, cone, and tree traits (Figure 4). The first five principal components have eigenvalues greater than 1. The first principal component (PC1) explains 26.90% of the total variation. In the positive direction of PC1, populations exhibit higher germination rates and a greater percentage of seeds per cone. Trees from the Veliki Stolac (P7), Tisovljak (P2), and Grad (P4) populations are notably positioned on this side of

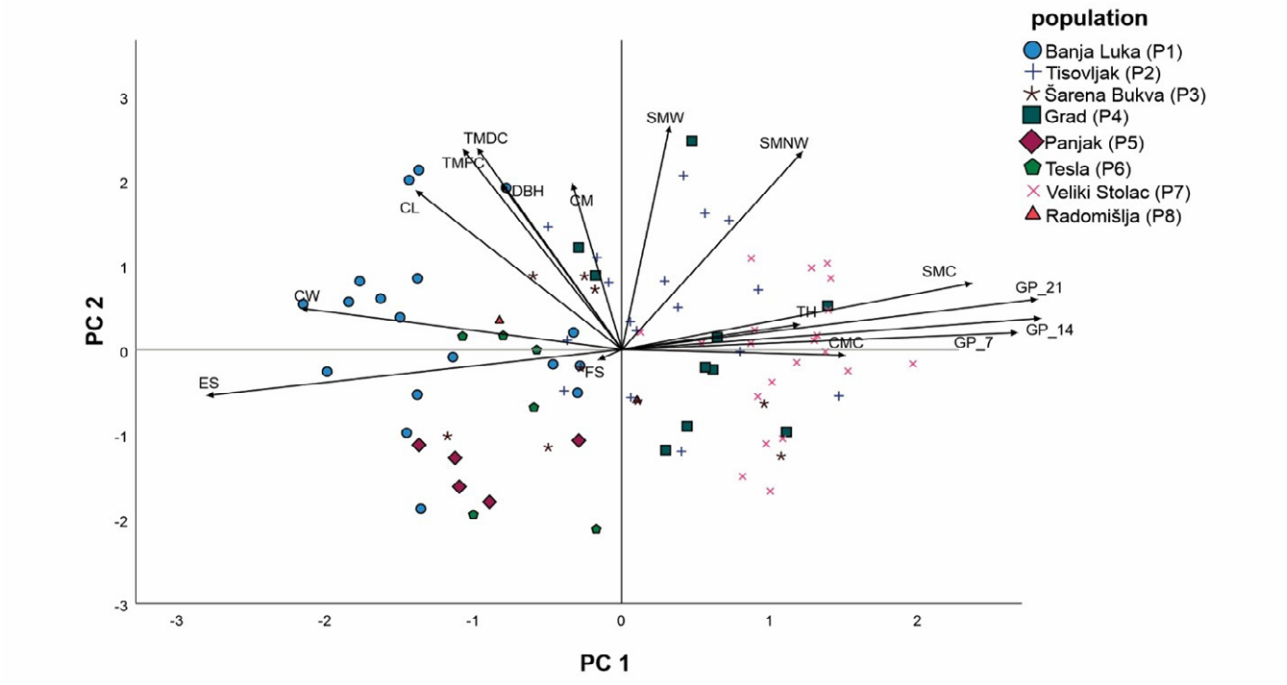

Figure 4 Principal component analysis (PCA) of the studied populations (P1–P8) based on analysed seed, cone, and tree traits. Analysed traits: GP_7 – % of germinated seeds on day 7; GP_14 – % of germinated seeds on day 14; GP_21 – % of germinated seeds on day 21; FS – % of full but ungerminated seeds; ES – % of empty seeds; TMFC – total fresh cone mass per tree; TMDC – total dry cone mass per tree; SMW – seed mass with wings; SMNW – seed mass without wings, CMC – cone moisture content; SMC – % of seeds per cone; CM – cone mass; CL – cone length; CW – cone width; TH – tree height; DBH – diameter at breast height.

Table 5 Pearson's correlation coefficients between the studied traits and scores of the first six principal components, along with eigenvalues, explained variance (%) and cumulative variance (%) for each component in the PCA (all components with eigenvalues greater than 1 and first bellow 1 are included. Studied traits: acronyms as defined in Table 4 and Figure 4.

Trait	PC – principal component					
	PC1	PC2	PC3	PC4	PC5	PC6
GP_7	0.797	0.067	-0.159	-0.305	-0.029	-0.099
GP_14	0.844	0.124	-0.357	-0.271	0.023	-0.044
GP_21	0.837	0.201	-0.407	-0.140	-0.001	-0.083
FS	-0.048	-0.042	0.376	0.716	-0.382	0.261
ES	-0.836	-0.184	0.221	-0.233	0.202	-0.052
TMFC	-0.292	0.804	0.333	-0.143	-0.166	-0.299
TMDC	-0.319	0.799	0.309	-0.188	-0.190	-0.263
SMW	0.096	0.893	0.305	-0.079	-0.223	0.053
SMNW	0.364	0.791	0.266	0.079	-0.207	0.076
CMC	0.451	-0.023	0.131	0.587	0.292	-0.463
SMC	0.705	0.265	-0.011	0.064	-0.055	0.487
CM	-0.101	0.663	-0.497	0.340	0.339	-0.125
CL	-0.415	0.635	-0.532	0.080	0.208	0.064
CW	-0.647	0.164	-0.441	-0.272	-0.065	0.283
TH	0.358	0.100	0.741	-0.119	0.424	0.153
DBH	-0.243	0.659	-0.448	0.234	0.277	0.249
Eigenvalues	4.57	4.24	2.86	1.46	1.11	0.94
Variance (%)	26.9	24.94	16.85	8.57	6.56	5.54
Cumulative variance (%)	26.9	51.84	68.69	77.27	83.82	89.36

the diagram. Conversely, the negative direction of PC1 is associated with a higher proportion of empty seeds. This component also shows grouping in the positive direction of cone-related traits. Panjak (P5) and Tesla (P6) populations are distinctly located in the lower-left quadrant of the PCA plot, reflecting smaller cones and lower germination energy and rates. This pattern corresponds with the negative axis of PC2, which accounts for 24.94% of the variation, yielding a cumulative variance of 51.84% (Table 5). PC2 predominantly represents traits related to seed mass. Additionally, the Banja Luka (P1) population stands out in the upper-left quadrant, indicating distinct cone traits compared to the other populations.

Multivariate diversity index

Based on all measured parameters, the MDI coefficients indicate the highest diversity in the P4–Grad (1.540) and P3–Šarena Bukva (1.515) populations, which are geographically close. In contrast, the P5–Panjak population exhibits the lowest diversity (0.617). The remaining studied populations show MDI values ranging from 1.076 and 1.497 (Table 1).

DISCUSSION

The dimensions of Serbian spruce cones vary significantly among the studied populations, highlighting potential ecological and genetic influences on their morphology. According to Vidaković (1982) and Idžojtić (2019), Serbian spruce cones typically range from 20 to 60 mm in length and 10 to 20 mm in width, while Krüssmann (1972) reports a length range of 30 to 60 mm and a width of 10 mm. The cones measured in Bosnia and Herzegovina, spanning eight populations of Serbian spruce, had an average length of 39.3 mm and a width of 16.1 mm. These measurements fall within the ranges previously documented in dendrological literature.

In our study, average cone length across natural populations ranged from 29.8 to 43.4 mm, whereas the urban population exhibited the longest cones, averaging 46.9 mm. Similarly, cone width in natural populations varied from 13.7 to 17.8 mm, while the urban population had an average width of 17.1 mm. These differences may be attributed to specific growth conditions in urban environments, including resource availability, microclimatic factors, and potential anthropogenic influences. Another possible explanation is that trees in the urban population in northern Bosnia and Herzegovina may originate from a different population rather than those analysed in this study. This possibility suggests that genetic differences among populations could play a role in the observed cone size variations. Further research, including genetic analyses, would be valuable in clarifying the origins and adaptability of urban populations compared to their naturally occurring counterparts.

As already stated in the introduction, previous research has primarily focused on genetic variability (Ballian et al. 2006, Nasri et al. 2008, Aleksić and Geburek 2010, Aleksić et al. 2017, Mataruga et al. 2020) and phenotypic analysis (Radovanović et al. 2014, Nikolić et al. 2015, Popović et al. 2020, Nikolić et al. 2025) based on needles, while studies examining cone morphology have been relatively scarce. One notable investigation was conducted by Isajev (1987), who analysed the variability of Serbian spruce trees across three planted forests in Serbia. His morphometric analysis of 1,000 cones harvested in 1981 and 1983 revealed significant variability between trees in cone length (20–70 mm), width (10–23 mm), and the number of seeds per cone (20–113 grains). The values for cone length and width in our study align with these findings. In addition, his study highlighted that cone size varied within 5% on the same tree across different harvest years, indicating strong genetic control of this trait (Isajev 1987). The obtained results showed that the Serbian spruce seeds from all three planted forests are characterized by very good quality (average germination rate was 90%).

In forest trees, reproductive dynamics and success are intricately linked to seed production, which varies across demographic stages and depends heavily on favourable environmental conditions (Moran and Clark 2012, Younginger et al. 2017). Fragmentation and climate change significantly affect seed quality and dispersal, both of which are crucial for species survival (McConkey et al. 2012). Empirical research highlights the complex relationship between seed size and germination time, with studies showing positive correlations between seed size and germination percentage and energy (Parker et al. 2006, Jones and Reekie 2006, Upadhaya et al. 2007, Souza and Fagundes 2014, Kaliniewicz et al. 2018), negative correlations (Simons and Johnston 2000, Gomez 2004, Tíscar and Lucas 2010, Hojjat 2011), and instances where no correlation exists (Larson 1963, Vaughton and Ramsey 1998, Tumpa et al. 2021). Serbian spruce populations with smaller/lighter seeds, such as those in the Tesla (P6) and Panjak (P5) populations with over 600,000 seeds per kilogram, exhibited poor germination rates, posing a threat to their already endangered status. This further supports the positive correlation observed between seed size and germination efficiency in Serbian spruce, as larger seeds likely store more nutrients that facilitate rapid germination and early seedling growth (Domic et al. 2020). Understanding these relationships is essential for conservation efforts aimed at preserving Serbian spruce populations. Improving seed quality and ensuring favourable germination conditions are critical strategies for mitigating the impact of environmental stressors on this endangered species.

Germination rates of Serbian spruce seeds in our study ranged from 20.4% to 81.4%, with an overall average of 51.8% across all investigated populations, aligning with findings for Norway spruce reported by Sarvas (1986) and Himanen et al. (2016). In contrast, Pintarić (1956, 1957, 1969) documented exceptionally high germination rates under optimal conditions, with one-year-old seeds reaching 97–98% and nearly 100% after 10 days. Furthermore, Pintarić (1970) demonstrated that proper storage preserves seed viability, as seeds aged up to three years still germinated at around 96%. However, the unspecified seed origin in Pintarić's studies limits the broader applicability of his findings. More recently, Cvjetković et al. (2013) observed significant differences in germination based on seed provenance, with seeds from planted forests exhibiting the highest germination rate at 84%, whereas those from natural populations germinated at 58.57% and 65.15%, showing extended dormancy periods. Refrigerator storage at ±4°C for six months improved germination by 20–28%, resembling the effects of stratification. The study conducted by Cvjetković et al. (2013) indicated considerable variation in seed germination depending on whether they were collected in natural or planted forests. However, this pattern was not observed in our study, where the Banja Luka (P1) population exhibited a germination rate of 47.5%, slightly below the average for all analysed populations. These results highlight the variability in germination success across different Serbian spruce populations and suggest that environmental factors and seed provenance may play a critical role in determining germination rates.

Further highlighting the variability of Serbian spruce seed germination, Ostojić and Dinić (2009) examined germination under natural conditions, revealing poor seed germination and seedling failure in the first year. Comparative experiments confirmed that Serbian spruce seedling establishment is heavily influenced by abiotic and biotic factors, including early spring and autumn frosts, dense forest canopy, thick layers of litter, herbaceous competition in open areas, and soil overheating in dry summer periods. Dinić (1988, 1989) previously reported similar findings, attributing poor seed germination and seedling survival to the sharp decline in tree numbers at the study location—from 40 trees recorded in early 1950s to only four remaining today. Later comparative experiments further validated these observations, confirming the sensitivity of Serbian spruce seeds and seedlings to multiple environmental pressures (Dinić 1990).

The failure of Serbian spruce natural regeneration is primarily linked to frequent fires (Aleksić et al. 2022), limited availability of suitable habitats, and strong

competition with other species (Tucić and Stojković 2001, Ostojić 2005). Additionally, recent studies suggest that poor genetic connectivity, even at small spatial scales, may further hinder seed dispersal (Aleksić and Geburek 2010, Mataruga et al. 2020). Despite these challenges, genetic diversity monitoring between two generations of Serbian spruce did not reveal negative effects on the genetic structure of the younger generation, even though only 25% of adult trees from the same population contributed to its formation, with 66% of pollen coming from unknown sources (Aleksić et al. 2022). These findings emphasize the strong link between the number of mature trees and seed quality, which is crucial for the species' survival in critical habitats. Moreover, the weak germination of seeds from endangered populations with fewer adult trees further supports the existence of mechanisms that help prevent inbreeding in this species (Mataruga and Milanović 2020).

In addition to confirming a positive correlation between seed mass and germination rate, we also established a statistically significant positive correlation between cone size (length and width) and mass, as well as between cone dimensions and seed mass. Similar findings have been reported by other authors investigating variability across different species of gymnosperms (Gómez 2004, Moya et al. 2007, Castanha et al. 2013, Memišević Hodžić et al. 2020, Poljak et al. 2020) and angiosperms (Poljak et al. 2021, Vidaković and Poljak 2024, Vidaković et al. 2025). According to Poljak et al. (2025), these results align with the general expectation that an increase in one cone/fruit dimension is often accompanied by proportional increases in other related dimensions, reflecting the interconnected nature of cone/fruit development. For instance, larger fruits tend to have a greater width and mass due to integrated growth processes (Vidaković et al. 2025).

Previous analyses of the genetic structure of Serbian spruce using SSR markers across 14 natural populations in Bosnia and Herzegovina (Mataruga et al. 2020) included all populations except Tesla (P6) and Banja Luka (P1), which are examined in the present study. When comparing the results of Bayesian clustering from that research with the outcomes of the principal component analysis (PCA) in this study, certain similarities in the population grouping patterns can be observed. However, clustering did not always reflect genetic origin. For example, samples from the Grad (P4) and Veliki Stolac (P7) populations were grouped together based on morphological and germination traits, yet SSR markers placed them in distinct genetic clusters. In contrast, genetically close populations like Šarena Bukva (P3) and Panjak (P5) were consistently grouped together across both phenotypic traits and molecular data. These findings suggest that, in addition to genetic variability, environmental conditions play a major role in shaping cone and seed morphology and affecting germination success. In addition to the differentiation of the urban population Banja Luka (P1) from the natural ones (P2–P8), a general trend was observed in the PCA biplot: samples from smaller natural populations tended to cluster within the section characterized by reproductive constraints, such as reduced germination rates and a higher proportion of empty seeds.

Genetic and phenotypic variations in Serbian spruce populations generally follow similar patterns, though not always in direct proportion. Previous research (Mataruga et al. 2020) identified Panjak (P5), Tisovljak (P2), and Grad (P4) as populations with the lowest contribution to total allelic diversity, while Veliki Stolac (P7), Šarena Bukva (P3), and Radomišlja (P8) exhibited the highest genetic variation. In our analysis, Šarena Bukva (P3) and Grad (P4) demonstrated the highest levels of phenotypic variability, based on multivariate diversity index (MDI) values of 1.515 and 1.540, respectively. Interestingly, despite Grad's (P4) lower genetic contribution, its high phenotypic diversity suggests environmental or developmental factors may be influencing morphological traits beyond what is reflected by neutral markers. Veliki Stolac (P7), although genetically diverse and reproductively vigorous, recorded a relatively modest MDI (1.076), possibly due to environmental homogeneity. The Panjak (P5) population—characterized by low genetic diversity, geographic isolation, and poor seed quality—also exhibited the lowest morphological variability (MDI = 0.617), reinforcing its designation as the most vulnerable unit. Overall, Serbian spruce populations display intrapopulation morphological variation comparable to that of other woody taxa, including *Salix eleagnos* Scop. (MDI = 1.154–3.480; Poljak et al. 2024), *Juniperus oxycedrus* (MDI = 1.506–1.772, Vidaković et al. 2024) and *J. deltoides* (MDI = 1.110–1.385, Vidaković et al. 2024), indicating a notable reservoir of phenotypic diversity despite the species' narrow distribution and endangered status.

CONCLUSIONS

Significant differences were observed in cone and seed traits, as well as in seed germination characteristics, among the examined Serbian spruce populations (seven natural and one urban). Germination rates were notably low and considerably lower compared to earlier findings. This decline is likely a consequence of climatic conditions during the cone harvest year and the fact that, for the first time, cones were collected from endangered populations

characterized by very limited number of mature trees. The biological quality of the seeds—reflected in their smaller size and low absolute mass—combined with the harsh environmental conditions in which these populations persist, led to a substantial loss of viable seeds. These constraints severely hinder natural regeneration and the sustainability of populations. This may also help explain why Serbian spruce tends to regenerate poorly in its native habitats.

The number of trees and their spatial distribution are crucial factors influencing cone and seed traits, as well as seed quality and germination rates at the population level. Threatened populations with fewer and more spatially isolated trees exhibit the poorest seed germination rates, suggesting the presence of a natural mechanism of blocking self-fertilization (inbreeding) in this species. This reproductive strategy, while beneficial for maintaining genetic integrity, may also reduce regeneration potential in fragmented and declining populations.

To ensure the long-term survival of Serbian spruce populations and support their recovery and expansion, conservation priorities should focus on protecting and restoring their native habitats and plant communities. At the same time, translocation and *ex-situ* conservation efforts could be targeted toward areas with more favourable environmental conditions, such as better-preserved vegetation, higher humidity, flatter terrain, and well-drained, loose soil. These combined measures would enhance the effectiveness of regeneration efforts and contribute to the conservation of the genetic resources of this valuable and critically endangered species.

ACKNOWLEDGMENT

The authors thank the Ministry of Agriculture, Forestry and Water Management in the Government of the Republic of Srpska for financial support; the public enterprise "Šume Republike Srpske" for logistical support in the field, and the representatives of the company "Arborist Banja Luka" for the cooperation and successful implementation of the cone collection.

REFERENCES

- Aldhous, J.R., 1972: Nursery practice. Forestry Commission Bulletin 43. Her Majesty's Stationery Office, London.
- Aleksić, M.J., T. Geburek, 2010: Mitochondrial DNA reveals complex genetic structuring in a stenoendemic conifer *Picea omorika* ((Panč.) Purk.) caused by its long persistence within the refugial Balkan region. Plant Systematics and Evolution 285: 1–11. https://doi.org/10.1007/s00606-009-0250-0
- Aleksić, J.M., A. Piotti, T. Geburek, G.G. Vendramin, 2017: Exploring and conserving a "microcosm": Whole-population genetic characterization within a refugial area of the endemic, relict conifer *Picea omorika*. Conservation Genetics 18 (4): 777–788. https://doi.org/10.1007/s10592-017-0926-x
- Aleksić, M.J., M. Mataruga, V. Daničić, B. Cvjetković, Đ. Milanović, G.G. Vendramin, C. Avanzi, A. Piotti, 2022: High pollen immigration but no gene flow via-seed into a genetic conservation unit of the endangered *Picea omorika* after disturbance. Forest Ecology and Management 510: 1–12. https://doi.org/10.1016/j.foreco.2022.120115
- Baeten, L., H. Jacquemyn, H. van Calster, E. van Beek, R. Devlaeminck, K. Verheyen, M. Hermy, 2009: Low recruitment across life stages partly accounts for the slow colonization of forest herbs. Journal of Ecology 97 (1): 109–117. https://doi.org/10.1111/j.1365-2745.2008.01455.x
- Ballian, D., R. Longauer, T. Mikić, L.D. Paule, D. Kajba, D. Gömöry, 2006: Genetic structure of a rare European conifer, Serbian spruce (*Picea omorika* (Panč.) Purk.). Plant Systematics and Evolution 260: 53–63. https://doi.org/10.1007/s00606-006-0431-z
- Bazzaz, F.A., 1991: Habitat selection in plants. The American Naturalist 137: 116–130.
- Castanha, C., M.S. Torn, M.J. Germino, B. Weibel, L.M. Kueppers, J. Harte, 2013: Conifer seedling recruitment across a gradient from forest to alpine tundra: effects of species, provenance, and site. Plant Ecology & Diversity 6 (3–4): 307–318. https://doi.org/10.1080/17550874.2013.781234
- Chen, F.Q., Z.Q. Xie, 2007: Reproductive allocation, seed dispersal and germination of *Myricaria laxiflora*, an endangered species in the Three Gorges Reservoir Area. Plant Ecology 191 (1): 67–75. https://doi.org/10.1007/s11258-006-9214-4
- Colin, J.Y., M.B. Linda, 2002: Assessing limitations on population growth in two critically endangered *Acacia* taxa. Biological Conservation 108 (1): 13–26. https://doi.org/10.1016/S0006-3207(02)00084-8
- Cvjetković, B., 2011: Uticaj mikobiota na dinamiku klijanja i mogućnost čuvanja sjemena Pančićeve omorike (*Picea omorika* Panč./Purkyně). Magistarski rad, Univerzitet u Beogradu, Šumarski fakultet. (in Serbian, with a summary in English)
- Cvjetković, B., M. Mataruga, V. Isajev, J. Lević, A. Lučić, V. Trkulja, Ž. Kremenović, 2013: Variability in germination and germination dynamics of differently treated seeds of Serbian spruce (*Picea omorika* Pančić/Purkyne). Genetika 45 (1): 109–119. https://doi.org/10.2298/GENSR1301109C
- Dinić, A., 1988: Uticaj korenovog sistema drveća i crnjuše (*Erica carnea* L.) na klijavost semena i prve faze rasta Pančićeve omorike u reliktnoj zajednici smrče, omorike i crnog bora na planini Tari. In: Proceedings of the Symposium "Proučavanje biljnog i životinjskog sveta sa aspekta problema zaštite i unapređenja životne sredine", Kragujevac, May 29–30, 1988, pp. 45–53.
- Dinić, A., 1989: Eksperimentalna ispitivanja klijavosti semena Pančićeve omorike na različitim staništima u rezervatu Crveni potok na planini Tari. Zaštita prirode 41–42: 87–95.
- Dinić, A., 1990: Ogledi sa setvom semena omorike u rezervatu Crvene stene i rasadniku na planini Tari. Zaštita prirode 43–44: 91–103.
- Domic, A., J. Capriles, G. Camilo, 2020: Evaluating the fitness effects of seed size and maternal tree size on *Polylepis tomentella* (Rosaceae) seed germination and seedling performance. Journal of Tropical Ecology 36: 115–122. https://doi.org/10.1017/S026646742000006
- Fenner, M. (ed.), 1985: Seed ecology. Chapman and Hall, London. https://doi.org/10.1007/978-94-009-4844-0
- Fernández, M., R. Tapias, 2022: Seed dormancy and seedling ecophysiology reveal the ecological amplitude of the threatened endemism *Picris willkommii* (Schultz Bip.) Nyman (Asteraceae). Plants 11 (15): 1981. https://doi.org/10.3390/plants11151981
- Gomez, J.M., 2004: Bigger is not always better: conflicting selective pressures on seed size in *Quercus ilex*. Evolution 58: 71–80. https://doi.org/10.1111/j.0014-3820.2004.tb01574.x

- Grossnickle, S., 2016: Restoration silviculture: An ecophysiological perspective – Lessons learned across 40 years. Reforesta 1: 1–36. https://doi.org/10.21750/REFOR.1.02.2
- Grossnickle, S., 2018: Seedling establishment on a forest restoration site: an ecophysiological perspective. Reforesta 6: 110–139. https://doi.org/10.21750/REFOR.6.09.62
- Grossnickle, S.C., V. Ivetić, 2017: Direct seeding in reforestation – a field performance review. Reforesta 4: 94–142. https://doi.org/10.21750/REFOR.4.07.46
- Gulias, J., A. Traveset, N. Riera, M. Mus, 2004: Critical stages in the recruitment process of *Rhamnus alaternus* L. Annals of Botany 93 (6): 723–731. https://doi.org/10.1093/aob/mch100
- Hensen, I., K. Wesche, 2006: Relationships between population size, genetic diversity and fitness components in the rare plant *Dictamnus albus* in Central Germany. Biodiversity and Conservation 15 (7): 2249–2261. https://doi.org/10.1007/s10531-004-7183-2
- Himanen, K., P. Helenius, T. Ylioja, M. Nygren, 2016: Intracone variation explains most of the variance in *Picea abies* seed weight: implications for seed sorting. Canadian Journal of Forest Research 46 (4): 470–477. https://doi.org/10.1139/cjfr-2015-0379
- Hojjat, S.S., 2011: Effect of seed size on germination and seedling growth of some lentil genotypes (*Lens culinaris* Medik.). International Journal of Agriculture and Crop Sciences 3: 1–5.
- Idžojtić, M., 2019: Dendrology: Cones, flowers, fruits and seeds. Elsevier – Academic Press, London. https://doi.org/10.1016/C2019-0-00771-6
- Iralu, V., H.S.A. Barbhuyan, K. Upadhaya, 2019: Ecology of seed germination in threatened trees: a review. Energy, Ecology and Environment 4: 189–210. https://doi.org/10.1007/s40974-019-00121-w
- Isajev, V., 1987: Oplemenjivanje omorike (*Picea omorika* Panč./Purkyne) na genetičko-selekcionim osnovama. Disertacija, Šumarski fakultet, Univerzitet u Beogradu. (in Serbian, with a summary in English)
- Jones, T.A., E.G. Reekie, 2006: Effect of seed size on seedling growth response to elevated CO_2 in *Picea abies* and *Picea rubens*. Plant Biology 9 (6): 766–775. https://doi.org/10.1055/s-2007-965251
- Kaliniewicz, Z., Z. Żuk, E. Kusińska, 2018: Physical properties of seeds of eleven spruce species. Forests 9 (10): 617. https://doi.org/10.3390/f9100617
- Kolb, A., K. Barsch, 2010: Environmental factors and seed abundance influence seedling emergence of a perennial forest herb. Acta Oecologica 36 (5): 507–513. https://doi.org/10.1016/j.actao.2010.07.003
- Krüssmann, G., 1972: Handbuch der Nadelgehölze. P. Parey, Berlin.
- Larson, M.M., 1963: Initial root development of *Ponderosa pine* seedlings as related to germination date and seed size. Forest Science 9: 456–460.
- Leck, M.A., V.T. Parker, R.L. Simpson, 2008: Seedling ecology and evolution. Cambridge University Press. https://doi.org/10.1017/CBO9780511815133
- Mataruga, M., D. Haase, V. Isajev, S. Orlović, 2012: Growth, survival, and genetic variability of Austrian pine (*Pinus nigra* Arnold) seedlings in response to water deficit. New Forests 43: 791–804. https://doi.org/10.1007/s11056-012-9351-7
- Mataruga, M., V. Isajev, M. Gardner, T. Christian, P. Thomas, 2011: *Picea omorika*. The IUCN Red List of Threatened Species 2011: e.T30313A9532613
- Mataruga, M., Đ. Milanović, 2020: Prirodne populacije Pančićeve omorike u Republici Srpskoj (Bosna i Hercegovina). Glasnik Šumarskog fakulteta Univerziteta u Banjoj Luci 30: 77–113. http://glasnik.sf.unibl.org/index.php/gsfbl/article/view/224/209
- Mataruga, M., Đ. Milanović, 2024: Smjernice za očuvanje Pančićeve omorike *in situ*. Republički zavod za zaštitu kulturno-istorijskog i prirodnog nasljeđa. Banja Luka, pp. 1–83.
- Mataruga, M., A. Piotti, V. Daničić, B. Cvjetković, B. Fussi, M. Konnert, G.G. Vendramin, J. Aleksić, 2020: Towards the dynamic conservation of Serbian spruce (*Picea omorika*) western populations. Annals of Forest Science 77: 1. https://doi.org/10.1007/s13595-019-0892-1
- McConkey, K.R., S. Prasad, R.T. Corlett, A. Campos-Arceiz, J.F. Brodie, H. Rogers, L. Santamaria, 2012: Seed dispersal in changing landscapes. Biological Conservation 146 (1): 1–3. https://doi.org/10.1016/j.biocon.2011.09.018
- Memišević Hodžić, M., A. Hajrudinović-Bogunić, F. Bogunić, V. Marku, D. Ballian, 2020: Geographic variation of *Pinus heldreichii* Christ from the Western Balkans based on cone and seed morphology. Dendrobiology 84 (1): 81–93. https://doi.org/10.12657/denbio.084.007
- Moran, E.V., J.S. Clark, 2012: Causes and consequences of unequal seedling production in forest trees: a case study in red oaks. Ecology 93 (5):1082–1094. https://doi.org/10.1890/11-1428.1
- Moya, D., J.M. Espelta, A. Rodrigo, 2007: Seed viability and germination success of *Pinus halepensis* and *P. nigra* after high-intensity crown fires. Forestry 80 (4): 431–439. https://doi.org/10.1093/forestry/cpm021
- Nasri, N., S. Bojović, G.G. Vendramin, B. Fady, 2008: Population genetic structure of the relict Serbian spruce, *Picea omorika*, inferred from plastid DNA. Plant Systematics and Evolution 271: 1–7. https://doi.org/10.1007/s00606-007-0594-2
- Nikolić, B., V. Tesević, I. Djordjević, P.D. Marin, S. Bojović, 2009: Essential oil variability in natural populations of *Picea omorika*, a rare European conifer. Chemistry & Biodiversity 6: 193–203. https://doi.org/10.1002/cbdv.200800085
- Nikolić, B., S. Bojović, P.D. Marin, 2015: Variability of morpho-anatomical characteristics of the needles of *Picea omorika* from natural populations in Serbia. Plant Biosystems 149 (1): 61–67. https://doi.org/10.1080/11263504.2013.810180
- Nikolić, B., V. Tešević, I. Đorđević, M. Jadranin, S. Bojović, P. Marin, 2024: Diversity of *Picea omorika* (Pančić) Purk. populations based on morpho-anatomical needle traits and bioclimatic parameters. South-East European Forestry 15 (2): 1–9.
- Nikolić, B.M., J. Božović, D. Ballian, S. Eremija, Z.S. Mitić, M.S. Marković, N. Čule, 2025: Microelements variability in needles of natural populations of *Picea omorika*. Šumarski list 149 (1–2): 35–43. https://doi.org/10.31298/sl.149.1-2.3
- Ostojić, D., 2005: Ekološki činioci prirodnog održavanja i obnove cenopopulacija Pančićeve omorike u NP Tara. Doktorska disertacija, Šumarski fakultet, Univerzitet u Beogradu. (in Serbian, with a summary in English)
- Ostojić, D., A. Dinić, 2009: Eksperimentalna fitocenološka ispitivanja prirodnog obnavljanja omorike (*Picea omorika* /Pančić/ Purkyně) u Nacionalnom parku Tara. Šumarstvo 61 (1–2): 23–35.
- Parker, W.C., T.L. Noland, A.E. Morneault, 2006: The effects of seed mass on germination, seedling emergence, and early seedling growth of eastern white pine (*Pinus strobus* L.). New Forests 32: 33–39. https://doi.org/10.1007/s11056-005-3391-1
- Parry, M., M.L. Parry, O. Canziani, J. Palutikof, P. Van der Linden, C. Hanson (eds.), 2007: Climate change 2007 – Impacts, adaptation and vulnerability: Working Group II Contribution to the Fourth Assessment Report of the IPCC, Vol. 4. Cambridge University Press, Cambridge.
- Pintarić, K., 1956: Kakav uticaj ima močenje sjemena Pančićeve omorike na proces klijanja. Narodni šumar 9–12: 378–380.

- Pintarić, K., 1957: Uticaj starosti sjemena i djelovanje svjetla na proces klijanja kod sjemena Pančićeve omorike (*Picea omorika* Panč.). Radovi Poljoprivredno-šumarskog fakulteta Univerziteta u Sarajevu II (2): 89–104.
- Pintarić, K., 1969: Sjetva sjemena Pančićeve omorike (*Picea omorica* Panch.) u šumskom rasadniku. Narodni šumar – Specijalno izdanje: 467–470.
- Pintarić, K., 1970: Konzerviranje sjemena Pančićeve omorike (*Picea omorika* Panč.) u hermetički zatvorenim posudama i uticaj starosti na klijavost. Šumarstvo 24: 3–12.
- Poljak, I., J. Vukelić, A. Vidaković, M. Vuković, M. Idžojtić, 2020: Variability of the populations of Scots pine (*Pinus sylvestris* L.) in the northwestern part of Mala Kapela according to the morphological characteristics of the needles and cones. Šumarski list 144 (11–12): 549–549. https://doi.org/10.31298/sl.144.11-12.1
- Poljak, I., N. Vahčić, Z. Liber, K. Tumpa, V. Pintar, I. Zegnal, A. Vidaković, B. Valković, D. Kajba, M. Idžojtić, 2021: Morphological and chemical diversity and antioxidant capacity of the service tree (*Sorbus domestica* L.) fruits from two eco-geographical regions. Plants 10 (8): 1691. https://doi.org/10.3390/plants10081691
- Poljak, I., Z. Šatović, A. Vidaković, K. Tumpa, M. Idžojtić, 2024: Population variability of rosemary willow (*Salix eleagnos* Scop.) based on the leaf morphometry: Evidence of small and large-leaf morphotypes. Šumarski list 148 (5–6): 219–236. https://doi.org/10.31298/sl.148.5-6.1
- Poljak, I., K. Tumpa, A. Vidaković, Z. Šatović, Z. Liber, M. Ježić, M. Ćurković-Perica, M. Idžojtić, 2025: Morphological variability of fruits and leaves allows delimitation between cultivated and wild chestnuts and their natural crosses. Genetic Resources and Crop Evolution 72: 3953–3968. https://doi.org/10.1007/s10722-024-02195-w
- Popović, V., A. Lučić, Lj. Rakonjac, Z. Maksimović, D. Ristić, 2020: Variability of morphological and anatomical characteristics of Serbian spruce (*Picea omorika* /Panč./Purkyne) needles of natural population located in the Milieševka River Canyon. Genetika 52: 1235–1248. https://doi.org/10.2298/GENSR2003235P
- Radovanović, B., J. Šinžar-Sekulić, T. Rakić, I. Živković, D. Lakušić, 2014: Variation in needle anatomy of *Picea omorika* (Pinaceae) plants belonging to different gene pools in natural populations on Tara Mt. in Serbia. Botanica Serbica 38 (2): 237–246.
- Rietz, R.C., O.W. Torgeson, 1937: Kiln temperatures for northern white pine cones. Journal of Forestry 35: 836–839.
- Sarvas, R., 1986: Investigations on the flowering and seed crop of *Picea abies*. Folia Forestalia 5: 836–839.
- Seppälä, R., A. Buck, P. Katila, 2009: Adaptation of forests and people to climate change. IUFRO World Series, vol. 22, Helsinki, pp. 224.
- Simons, A.M., M.O. Johnston, 2000: Variation in seed traits of *Lobelia inflata* (Campanulaceae): sources and fitness consequences. American Journal of Botany 87: 124–132.
- Souza, M.L., M. Fagundes, 2014: Seed size as key factor in germination and seedling development of *Copaifera langsdorffii* (Fabaceae). American Journal of Plant Sciences 5: 2566–2573.
- StatSoft Inc., 2004: STATISTICA (Data Analysis Software System), Version 7.0. StatSoft Inc., Tulsa, Oklahoma. https://www.statsoft.com
- Tíscar, P., M. Lucas, 2010: Seed mass variation, germination time and seedling performance in a population of Pinus nigra subsp. salzamannii. Forest Systems 19: 344–353. https://doi.org/10.5424/fs/2010193-9094
- Tucić, B., B. Stojković, 2001: Shade avoidance syndrome in *Picea omorika* seedlings: a growth-room experiment. Journal of Evolutionary Biology 14 (3): 444–455. https://doi.org/10.1046/j.1420-9101.2001.00291.x
- Tumpa, K., A. Vidaković, D. Drvodelić, M. Šango, M. Idžojtić, I. Perković, I. Poljak, 2021: The effect of seed size on germination and seedling growth in sweet chestnut (*Castanea sativa* Mill.). Forests 12 (7): 858. https://doi.org/10.3390/f12070858
- Tumpa, K., Z. Liber, Z. Šatović, J. Medak, M. Idžojtić, A. Vidaković, J. Vukelić, I. Šapić, P. Nikl, I. Poljak, 2022: High level of phenotypic differentiation of common yew (*Taxus baccata* L.) populations in the north-western part of the Balkan Peninsula. Forests 13 (1): 78. https://doi.org/10.3390/f13010078
- Upadhaya, K., H.N. Pandey, P.S. Law, 2007: The effect of seed mass on germination, seedling survival and growth in *Prunus jenkinsii* Hook.f. & Thoms. Turkish Journal of Botany 31: 31–36.
- Vaughton, G., M. Ramsey, 1998: Sources and consequences of seed mass variation in *Banksia marginata* (Proteaceae). Journal of Ecology 86: 563–573.
- Vidaković, M., 1982: Četinjače: morfologija i varijabilnost. JAZU, Sveučilišna naklada Liber, Zagreb.
- Vidaković, A., Z. Šatović, K. Tumpa, M. Idžojtić, A. Barišić, I. Poljak, 2024: Secondary sexual dimorphism and morphological diversity in two allopatric juniper species: *Juniperus oxycedrus* and *J. deltoides*. Acta Botanica Croatica 83 (1): 14–25. https://doi.org/10.37427/botcro-2024-007
- Vidaković, A., I. Poljak, 2024: Fruit morphological variability and chemical composition in European wild pear (*Pyrus pyraster* (L.) Burgsd.) natural populations. Genetic Resources and Crop Evolution 71: 4315–4330. https://doi.org/10.1007/s10722-024-01912-9
- Vidaković, A., M. Radunić, I. Poljak, 2025: Variation in chemical composition and fruit morphometric traits of almond-leaved pear (*Pyrus spinosa* Forssk.) natural populations. Genetic Resources and Crop Evolution 72: 1495–1510. https://doi.org/10.1007/s10722-024-02059-3
- Xu, J., P. Xiao, T. Li, Z. Wang, 2022: Research progress on endangered plants: a bibliometric analysis. Biodiversity and Conservation 31: 1125–1147. https://doi.org/10.1007/s10531-022-02392-y
- Xu, Y., R. Zang, 2023: Conservation of rare and endangered plant species in China. iScience 26: 106008. https://doi.org/10.1016/j.isci.2023.106008
- Yates, C.J., L.M. Broadhurst, 2002: Assessing limitations on population growth in two critically endangered *Acacia* taxa. Biological Conservation 108 (1): 13–26. doi:10.1016/S0006-3207(02)00084-8
- Younginger, B.S., D. Sirova, M.B. Cruzan, D.J. Ballhorn, 2017: Is biomass a reliable estimate of plant fitness? Applied Plant Sciences 5 (2): 1600094. https://doi.org/10.3732/apps.1600094

https://doi.org/10.31298/sl.149.11-12.3

Izvorni znanstveni članci – Original scientific papers
Šumarski list, 11-12 (2025): 545-557

ASSESSMENT OF GROWTH PARAMETERS IN *Pinus sylvestris* L. STANDS: FIVE-YEAR RESULTS OF PRECOMMERCIAL THINNING

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SUMMARY

Determining the optimal intensities for precommercial thinning (PCT) in *Pinus sylvestris* stands, which hold significant ecological and economic value in Türkiye, is crucial for enhancing growth performance and ensuring well-formed stems. This study investigates the effects of various PCT intensities on the growth parameters of young, naturally regenerated stands located in the Western Black Sea and Central Anatolia regions of Türkiye. A total of 24 experimental plots (4 PCT intensities × 3 replications × 2 sites) were established in thicket-stage stands, and four PCT treatments were applied: T1 (classic), T2 (0.75–1.0 m spacing), T3 (1.5–2.0 m spacing), and a control (unthinned). Diameter at breast height, height, total basal area, and total volume were measured at the end of each growing season for five consecutive years. The results indicated that PCT intensity had a significant effect ($p < 0.05$) on all measured growth parameters. Both DBH and height increments were positively correlated with increased PCT intensity, with the greatest gains observed in the T1 and T3 PCT treatments. In particular, the relative increment values increased in parallel with the rise in PCT intensity in all measured growth parameters. In conclusion, leaving around 3000–3500 stems per hectare during PCT provides the best outcomes in terms of growth and stand structure. The findings suggest that PCT interventions should be performed on a 3–5 year cycle to maximize growth potential and maintain forest health.

KEY WORDS: Scots pine, stand density, thicket stage, tending operation

INTRODUCTION

The application of appropriate silvicultural interventions at the right time and in the correct intensity is critical for effective wood production and controlling stand development in forest ecosystems (Turna et al. 2017). Due to the wide variations in species diversity and stand compositions in Türkiye's forests, which are influenced by different site conditions, these factors play a direct role both in determining the techniques to be used for regeneration and tending and in the success of such interventions (Özel and Ertekin 2010, Atar 2022). Operations such as precommercial thinning and thinning help trees grow as planned, improve wood quality and yield, shorten rotation periods, enhance stand stability, and support biodiversity (Klädtke 2001, Zeide 2001, Nutto et al. 2005, Fahlvik et al. 2018). The planning and implementation of these interventions are essential steps in forest management to ensure the sustainability of the functions provided by forests (Danusevicius et al. 2016).

A basic silvicultural technique called precommercial thinning (PCT) is used in regenerated and juvenile stands to remove trees with little to no economic value in order to enhance and speed up the growth performance of the remaining trees (Chase et al. 2016, Güney et al. 2021). PCT plays a critical role in forest management

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by reducing competition, regulating stand structure, and improving growth conditions (soil, light, water, and nutrients) (Fahlvik et al. 2018). In addition to maintaining the intended species composition and accelerate the growth of the selected individuals, this intervention is used to reduce stress and improve wood quality (Weiskittel et al. 2009, Prévost and Gauthier 2012). PCT is of great importance in achieving desired wood characteristics in the future and reducing the rotation age (Fleming 1994). Additionally, by reducing stand density in the early developmental stages, this intervention promotes the effective use of forest resources, enhancing both vertical and radial growth rates of trees (Smith 1986, Thibodeau et al. 2000).

Like all tending interventions, precommercial thinning must be applied in young stands at the right time and with the appropriate intensity, otherwise, it may lead to irreversible economic losses in forest management (Rice et al. 2001, Eler et al. 2004, Huuskonen and Hynynen 2006). In Scots pine stands, precommercial thinning (PCT) primarily aims to remove undesired individuals—including diseased, suppressed, or poorly formed trees as well as dominant, wide-crowned individuals—that hinder the development of neighboring trees. This intervention regulates stand structure, promotes more uniform growth among selected crop trees, enhances wood production, and improves the timing and economic returns of the first commercial thinning (Frda 1996, Fahlvik et al. 2005). Additionally, PCT plays a significant role in the normal development of tree crowns (Oker-Blom et al. 1988). Careful adjustment of the appropriate PCT intensity and timing is crucial for maximizing the overall growth and yield within the stand (Karlsson et al. 2013, Ulvcrona et al. 2017, Güney et al. 2022).

PCT has proven effective in lowering stand density, enhancing tree growth, fostering future understory development, preserving the desired species composition, and increasing the slenderness ratio, which reflects the mechanical stability of trees againvst damage by wind or snow (Pothier 2002, Pitt and Lanteigne 2008). Along with increasing light availability, which is a key factor for growth (Pothier and Margolis 1991), PCT can also improve nutrient accessibility and water availability (Thibodeau et al. 2000), enhance wind resistance (Achim et al. 2005), and promote uniformity in wood structure (Koga et al. 2002). When applied in young stands composed of different tree species, PCT also promotes the development of individual trees (Simard et al. 2004, Splawinski et al. 2017).

Multiple studies on PCT and various thinning practices have indicated considerable increases in height, diameter, and basal area (Sıvacıoğlu et al. 2006, Skovsgaard 2009, Reventlow et al. 2019, Niemistö and Valkonen 2021, Bayar and Alkan 2023). These interventions are seen as particularly effective methods for enhancing individual tree growth at younger ages (Egnell and Ulvcrona 2015, Reventlow et al. 2019, Wotherspoon et al. 2020).

Scots pine (*Pinus sylvestris* L.), one of the most widely distributed pine species, spans a vast geographic range across Europe and Asia, approximately 3,700 km in width and 14,700 km in length. Its northern boundary reaches the 70th parallel (northern Scandinavia), its southern boundary lies at around the 37th northern parallel (Sierra Nevada, Spain), its western boundary extends to approximately 8°W longitude (Spain), and its eastern boundary reaches as far as 141°E longitude (Russia) (Figure 1) (Pravdin 1969, Boratynski 1991). In Türkiye, Scots pine has a natural distribution between the latitudes 38°34' – 41°48'N and longitudes 28°00' – 43°05'E, starting west of Eskişehir, passing through Sarıkamış, and extending to the Caucasus. It grows at elevations ranging from 1000 to 2500 meters a.s.l., either as pure stands or in mixtures with other species. The vertical distribution of Scots pine varies from the sea level in Sürmene-Trabzon (Çamburnu) to altitudes as high as 2700 meters in Sarıkamış (Kayacık 1963, Saatçioğlu 1976, Turna 2003).

For *P. sylvestris*, a species of high ecological and economic value, determining the optimal PCT conditions is crucial for obtaining well-formed stems and achieving higher economic returns. Several studies have been conducted in various countries where Scots pine is distributed, focusing on the effects of PCT interventions on stand development (Pettersson 1993, Varmola and Salminen 2004, Ulvcrona et al. 2007, Karlsson et al. 2013, Fahlvik et al. 2018). In Türkiye, given the species' broad distribution range, a limited number of studies have been conducted, such as those by Öncül et al. (2016) in the Eastern Anatolia Region and Sıvacıoğlu et al. (2006) in the Central Black Sea Region. However, considering the varying micro and macro ecological factors within the species' extensive range in Türkiye, it is essential to conduct thinning-related studies in different regions of its distribution area. Therefore, this study was carried out in Scots pine stands representing the Western Black Sea (Karabük-Eskipazar province) and Central Anatolia (Çankırı-Çerkeş province) regions of Türkiye. The study aims to investigate the effects of various PCT levels on the growth variables of young *P. sylvestris* stands over a five-year growth period and to find the most suitable PCT intensity. The development of young *P. sylvestris* stands is hypothesized to be significantly impacted by varying PCT intensities. Specifically, by examining the effects of different PCT intensities on growth variables such as diameter, height, basal area, and volume, this study aims to contribute to forest management and the development of silvicultural prescriptions.

MATERIALS AND METHODS

Study area

The study areas are located in natural young *P. sylvestris* stands in Karabük-Eskipazar, situated in the Western Black Sea Region of Türkiye, and in Çankırı-Çerkeş, located in the Central Anatolia Region (Figure 1). The plots were chosen from naturally regenerated Scots pine stands in the early development (thicket) stage. Before our investigation, no precommercial thinning had been done, and these stands had uniform stand characteristics.

The Karabük-Eskipazar plots (41°02'32"N, 32°31'28"E) are located at an average altitude of 1390–1520 meters above sea level, with a slope of 30–50% and a south-southeast aspect. The experimental plots, predominantly composed of non-rocky and stone-free to slightly stony soils in terms of surface rockiness and stoniness, are located on moderate slopes. The litter layer thickness within the plots varies between 2 and 5 cm. In the experimental plots, the amount of litter per unit area was determined to average 41.05 t/ha, with the mean pH of the litter recorded as 5.27. It was determined that the bedrock in the experimental plot consists of sedimentary rocks, specifically sandstone. The soils in the experimental plot are classified as very stony-skeletal in terms of profile stoniness. Generally identified as clay soil, the experimental plot soils fall under the category of "fine-textured (heavy) soils". The average composition of the soil was determined to be 21.97% sand, 45.88% clay, and 32.15% silt. According to long-term averages, the mean, highest, and lowest temperatures are 13.3°C, 32°C, and -7°C during the year, respectively, with a total annual precipitation of 735 mm.

The Çankırı-Çerkeş plots (40°43'05"N, 32°48'39"E) are situated at an average altitude of 1320–1530 meters above sea level, with a slope of 20–40% and a north-northeast aspect. The experimental plots, characterized by non-rocky and stone-free to slightly stony soils in terms of surface rockiness and stoniness, are situated on moderate slopes and ridges. The thickness of the litter layer within the plots ranges between 1.5 and 3 cm. In the experimental area, the average amount of litter per unit area was determined to be 27.97 t/ha, with the mean pH of the litter recorded as 5.92. It was determined that the bedrock in the experimental plot consists of sedimentary rocks, specifically limestone. The soils in the experimental plot are classified as very stony-skeletal in terms of profile stoniness. Identified as clay soil, the experimental plot soils fall under the category of "fine-textured (heavy) soils". The average composition of the soil was determined to be 31.80% sand, 44.51% clay, and 23.69% silt. According to long-term averages, the recorded mean, highest, and lowest temperatures are 11.4°C, 32°C, and -9°C, respectively, with an annual average precipitation amount of 616 mm. Climate data were obtained from the WorldClim database, which provides global climate data as spatial data layers (Fick and Hijmans 2017). All soil property analyses were conducted in the laboratories of the Eskişehir Forest Soil and Ecology Research Institute Directorate. Descriptive information regarding the stand, soil, and climate characteristics of the experimental plots is presented in Table 1. Dominant height values in Table 1 represent the average height of the 100 tallest trees per hectare.

Figure 1 The global distribution of Scots pine and the geographical location of the plots (Caudullo et al. 2017).

Table 1 Descriptive information regarding the stand, soil, and climate characteristics of the experimental plots.

Variables	Karabük-Eskipazar	Çankırı-Çerkeş
Stand properties		
Elevation (m)	1390-1520	1320-1530
Aspect	South-Southeast	North-Northeast
Slope (%)	30-50	20-40
Stand age (years)	32	36
Dominant tree height (m)	9.18	9.35
Mean stem diameter (cm)	5.81	5.24
Site index class	II	II
Soil Properties		
Litter layer thickness (cm)	2-5	1.5-3
Amount of litter (t/ha)	41.05	27.97
Mean pH of litter	5.27	5.92
Sand (%)	21.97	31.80
Silt (%)	32.15	23.69
Clay (%)	45.88	44.51
Climatic attributes		
Mean annual temperature (°C)	13.3	11.4
Mean maximum temperature (°C)	32.0	32.0
Mean minimum temperature (°C)	-7.0	-9.0
Annual precipitation (mm)	735	616

Experimental design and treatments

PCT interventions were applied at four different levels, including a control. In both plots, a randomized block design with three replications was used, resulting in 24 treatment plots (4 PCT treatments × 3 replications × 2 sites). A 5-meter-wide buffer zone was established around each plot. Due to the natural variability in tree density across Scots pine stands at the thicket stage, and in order to ensure comparability across treatments, each plot was arranged to contain exactly 50 trees after thinning. This required adjusting the plot size according to thinning intensity, resulting in plot areas ranging from 50 to 150 m². This approach allowed for balanced sample sizes in statistical analyses and helped prevent disproportionate representation of treatments. Tree spacing was determined based on the targeted thinning intensity to ensure both consistency in tree number and spatial homogeneity across plots (Varmola and Salminen 2004, Zhang et al. 2006, Weiskittel et al. 2009, Wallentin and Nilsson 2011, Güney et al. 2021, Atar 2022).

Control (C): The control (unthinned) plots were not subjected to precommercial thinning and were allowed to grow naturally. In the control (unthinned) sample plots, 50 trees were retained, and each control plot was approximately 50 m² in size. The tree density per hectare was 11350 trees/ha in the Eskipazar plot and 12000 trees/ha in the Çerkeş plot.

Treatment-1 (T1): In the traditional treatment, precommercial thinning was conducted in such a way that there was a canopy gap of one crown between two tree crowns. A total of 50 trees were maintained in each replicate, and the plot size was approximately 150 m². The tree density per hectare was 3390 trees/ha in the Eskipazar plot and 3310 trees/ha in the Çerkeş plot.

Treatment-2 (T2): In the second treatment, the precommercial thinning plots had a spacing of approximately 0.75 to 1.0 meters between the trees. A total of 50 trees were left to grow in each replicate, with a plot size of approximately 70 m². The tree density per hectare was 7320 trees/ha in the Eskipazar plot and 7680 trees/ha in the Çerkeş plot.

Treatment-3 (T3): In the third treatment, the spacing between the trees in the precommercial thinning plots was set at approximately 1.5 to 2.0 meters. A total of 50 trees were left in each replicate, with a plot size of approximately 140 m². The tree density per hectare was 3570 trees/ha in the Eskipazar plot and 3500 trees/ha in the Çerkeş plot.

Measurements

All trees in the plots were marked with a stripe of oil-based paint at breast height (1.30 m) and numbered. Subsequently, the diameters at breast height (DBH) of the trees were measured from this marked point. The heights (H) of the trees were determined using a Vertex-IV hypsometer. Among the selected trees, individuals with healthy, tall, well-formed, strong, straight, and undamaged crowns were preferred. Precommercial thinning interventions commenced after the end of the 2014 growing season. Immediately after the intervention, the diameters and heights of the remaining trees were measured. The measurements were repeated on the same trees at the end of the first (2015), second (2016), third (2017), fourth (2018), and fifth (2019) growing season. However, height measurements for the 2017 growing

season could not be conducted. Based on these measurements, total basal area (BA) and volume (V) values were calculated. For volume calculation of the trees in the plots, a two-entry tree volume equation developed by Şenyurt (2011) for Scots pine stands in the Western Black Sea Region was used. The equation, which estimates volume based on the DBH and height of each tree, is presented below.

$$V = 1{,}003506 \exp(-3{,}062228 + 2{,}195122 \times \ln d - 0{,}058577 \times \ln d^2 + 0{,}669187 \times \ln h + 0{,}080075 \times \ln h^2) \quad (1)$$

The equation provided above estimates the single-tree stem volume (dm^3) including bark, based on tree height (m) and diameter at breast height (cm). The statistical values for the equation are as follows: $R^2 = 0.996$, $F = 589{,}762.29$ ($P < 0.000$), SE = 0.083. (R^2: coefficient of determination, F: F test value, SE: standard error of estimate.)

Statistical analysis

The SPSS (26.0) software was used for all statistical analyses. To assess whether the initial values of the treatments were homogeneous before the effect of the PCT, a one-way ANOVA was performed by measuring the individuals left in the experimental plots immediately after the PCT. The results revealed that there were some variations in the initial DBH, height, basal area, and volume values. Therefore, an analysis of covariance (ANCOVA) model was applied to evaluate the periodic annual increments and adjust for the initial differences among the PCT treatments.

$$Y_{ij} = \mu + \alpha i + \beta\left(X_{ij} - \bar{X}_i\right) + E_{ij} \quad (2)$$

In Equation (2), Y_{ij} represents the dependent variable for the i^{th} individual at the j^{th} factor level, μ is the overall mean, αi denotes the mean response variable that exceeds the overall mean for treatment i, β is the regression coefficient, X_{ij} is the j^{th} observation of the covariate for the i^{th} treatment level, and E_{ij} is the unobserved error term associated with treatment i and replication j.

Because of the initial differences, several researchers have employed the analysis of covariance (ANCOVA) (Lindgren and Sullivan 2013, Atar 2022, Güney et al. 2022). Additionally, the significance levels ($p < 0.05$) for numerous pairwise comparisons between the PCT intensities were evaluated using Bonferroni's multiple comparison t-test (Özdamar, 2013).

$$t' = \frac{\bar{X}_i - \bar{X}_j}{\sqrt{\frac{S^2}{n} + \frac{S^2}{n}}} = \frac{\bar{X}_i - \bar{X}_j}{\sqrt{\frac{2S^2}{n}}} = \frac{\bar{X}_i - \bar{X}_j}{\sqrt{\frac{2M_{SE}}{n}}} \quad (3)$$

In Equation (3), X_i and X_j = treatments, M_{SE} = the mean squared error, S = the standard deviation.

RESULTS

Based on PCT intensities, DBH and BA were recorded in 2014, 2015, 2016, 2017, 2018, and 2019 (Table 2). Measurements taken immediately after the PCT in the Eskipazar plot showed that the average DBH was 5.12 cm, 6.49 cm, 6.48 cm, and 7.00 cm for the control, T1, T2, and T3 plots, respectively. Five growing seasons after the PCT, the average DBH was 7.13 cm in the control plot, 10.01 cm in T1, 9.43 cm in T2, and 10.32 cm in T3. In the Çerkeş plot, the largest DBH was observed in the T1 treatment, both in 2014 and 2019. As anticipated, the average diameter values rose in proportion to the increasing PCT intensities. At the end of the fifth growing season, the lowest total basal area was recorded in the T1 treatment (29.10 m^2/ha) in the Eskipazar plot and in

Table 2 Mean ± SE diameter at breast height (DBH) and basal area (BA) of trees after PCT at four intensities.

Plot	Variable	PCT intensity	Measurement years					
			2014	2015	2016	2017	2018	2019
Eskipazar	DBH (cm)	C (11350)	5.12±0.18	5.59±0.19	6.06±0.20	6.54±0.21	6.86±0.22	7.13±0.23
		T1 (3390)	6.49±0.24	7.20±0.26	8.01±0.28	8.88±0.30	9.46±0.31	10.01±0.33
		T2 (7320)	6.48±0.21	7.13±0.22	7.80±0.24	8.49±0.25	8.97±0.26	9.43±0.28
		T3 (3570)	7.00±.24	7.66±0.25	8.44±0.27	9.30±0.30	9.85±0.31	10.32±0.33
	BA (m^2/ha)	C (11350)	26.37±1.80	31.09±2.04	36.44±2.35	42.21±2.69	46.58±3.02	50.35±3.30
		T1 (3390)	12.54±0.84	15.32±1.00	18.87±1.22	23.08±1.47	26.04±1.61	29.10±1.79
		T2 (7320)	26.83±1.58	32.26±1.85	38.50±2.19	45.43±2.56	50.57±2.80	55.91±3.08
		T3 (3570)	15.03±0.98	17.88±1.12	21.67±1.36	26.29±1.66	29.39±1.80	32.65±1.96
Çerkeş	DBH (cm)	C (12000)	4.60±0.21	4.97±0.22	5.34±0.23	5.80±0.24	6.08±0.25	6.28±0.26
		T1 (3310)	7.18±0.30	7.93±0.33	8.74±0.37	9.45±0.39	10.01±0.41	10.43±0.42
		T2 (7680)	6.02±0.21	6.50±0.22	6.96±0.23	7.52±0.25	7.91±0.27	8.22±0.28
		T3 (3500)	6.40±0.24	6.94±0.25	7.53±0.27	8.10±0.28	8.53±0.29	8.90±0.30
	BA (m^2/ha)	C (12000)	23.70±2.12	27.41±2.38	31.38±2.68	36.71±3.07	40.29±3.39	42.98±3.58
		T1 (3310)	15.29±1.17	18.60±1.46	22.72±1.85	26.38±2.11	29.52±2.32	32.03±2.49
		T2 (7680)	23.99±1.34	27.88±1.88	31.91±2.14	37.17±2.48	41.32±2.84	44.68±3.10
		T3 (3500)	12.45±0.86	14.53±0.97	17.05±1.16	19.69±1.32	21.79±1.43	23.66±1.54

Notes: C, Control; T1: Classic, T2: 0.75–1.0 m, T3: 1.5–2.0 m

the T3 treatment (23.66 m^2/ha) in the Çerkeş plot. Conversely, the highest values were found in the T2 treatment in both plots for the more intensive PCT.

At the end of the fifth growing season, the highest height values were recorded in the T1 treatment in both plots. In terms of total volume per hectare, the highest values were observed in the T2 treatment in both plots, with 242.16 m^3/ha and 198.22 m^3/ha , respectively (Table 3).

Table 3 Mean ± SE height (H) and volume (V) of trees after PCT at four intensities.

Plot	Variable	PCT intensity	Measurement years				
			2014	2015	2016	2018	2019
Eskipazar	H (m)	C (11350)	5.73±1.13	6.05±1.16	6.43±1.22	7.04±1.24	7.35±1.26
		T1 (3390)	6.01±1.73	6.42±1.76	6.86±1.83	7.73±1.93	8.28±2.02
		T2 (7320)	6.29±1.40	6.67±1.45	7.10±1.50	7.87±1.63	8.27±1.70
		T3 (3570)	5.94±1.23	6.36±1.26	6.80±1.26	7.64±1.38	8.15±1.51
	V (m^3/ha)	C (11350)	81.62±6.28	101.02±7.51	125.36±9.19	173.38±12.59	195.02±15.25
		T1 (3390)	42.24±3.51	54.49±4.44	71.01±5.6	107.79±8.20	127.58±9.46
		T2 (7320)	91.29±6.32	115.33±7.77	145.56±9.77	209.11±13.63	242.16±15.63
		T3 (3570)	47.53±3.71	59.88±4.45	77.01±5.73	115.48±8.35	136.46±9.77
Çerkeş	H (m)	C (12000)	4.90±0.10	5.19±0.11	5.49±0.11	6.13±0.12	6.54±0.12
		T1 (3310)	7.21±0.22	7.61±0.23	8.04±0.24	8.86±0.25	9.34±0.25
		T2 (7680)	6.59±0.15	6.95±0.15	7.34±0.15	7.97±0.15	8.41±0.16
		T3 (3500)	5.98±0.12	6.34±0.12	6.74±0.12	7.43±0.13	7.86±0.14
	V (m^3/ha)	C (12000)	65.16±6.65	79.04±7.83	95.12±9.29	134.57±12.83	152.17±14.26
		T1 (3310)	61.71±5.92	78.93±7.67	101.47±10.08	142.60±13.67	161.80±15.14
		T2 (7680)	84.82±6.81	103.13±8.20	124.15±9.85	174.24±14.11	198.22±16.16
		T3 (3500)	39.77±3.16	48.88±3.79	60.67±4.77	84.69±6.39	96.87±7.20

Notes: C, Control; T1: Classic, T2: 0.75–1.0 m, T3: 1.5–2.0 m

In the Eskipazar plot, the 5-year DBH increments for the control, T1, T2, and T3 PCT treatments were 2.34 cm, 3.42 cm, 2.83 cm, and 3.08 cm, respectively. The results indicate that as the PCT intensity increased, the diameter growth also increased (Figure 2). Moreover, the 5-year total basal area increments were 19.41 m^2/ha in the control, 23.90 m^2/ha in the T1 plot, 24.12 m^2/ha in the T2 plot, and 22.82 m^2/ha in the T3 plot. Regarding the 5-year total basal area per hectare, the T2 treatment displayed the greatest value. The control, T1, T2, and T3 plots in the Çerkeş plot had 5-year DBH increases of 2.13 cm, 2.90 cm, 2.21 cm, and 2.38 cm, respectively. According to the findings, the control plot's total basal area increased by 15.67 m^2/ha between 2014 and 2019, while the T1 PCT's was 19.57 m^2/ha , the T2 PCT's was 16.86 m^2/ha , and the T3 PCT's was 16.20 m^2/ha (Table 4).

Table 4 Increments of DBH and BA regarding PCT intensities and years of measurements.

Plot	Variable	PCT intensity	Increment by years				
			2014-2015	2014-2016	2014-2017	2014-2018	2014-2019
Eskipazar	DBH (cm)	C	0.52±0.01	1.07±0.03	1.63±0.04	2.00±0.07	2.34±0.07
		T1	0.70±0.02	1.48±0.02	2.33±0.05	2.89±0.08	3.42±0.07
		T2	0.64±0.01	1.29±0.04	1.95±0.04	2.40±0.07	2.83±0.06
		T3	0.63±0.02	1.36±0.03	2.17±0.05	2.53±0.08	3.08±0.07
		p	0.000	0.000	0.000	0.000	0.000
	BA (m^2/ha)	C	3.92±0.12	8.26±0.26	12.96±0.45	16.51±0.54	19.41±0.61
		T1	4.05±0.14	9.22±0.30	15.16±0.52	19.44±0.62	23.90±0.70
		T2	4.57±0.12	9.71±0.26	15.48±0.45	19.72±0.54	24.12±0.61
		T3	3.75±0.14	8.69±0.31	14.53±0.52	18.58±0.63	22.82±0.71
		p	0.000	0.000	0.000	0.000	0.000
Çerkeş	DBH (cm)	C	0.47±0.02	0.93±0.04	1.49±0.05	1.86±0.06	2.13±0.07
		T1	0.68±0.02	1.43±0.04	2.05±0.06	2.54±0.07	2.90±0.07
		T2	0.49±0.02	0.96±0.03	1.52±0.06	1.91±0.07	2.21±0.07
		T3	0.52±0.02	1.07±0.04	1.62±0.05	2.03±0.06	2.38±0.07
		p	0.000	0.000	0.000	0.000	0.000
	BA (m^2/ha)	C	3.04±0.14	6.21±0.31	10.66±0.44	13.49±0.53	15.67±0.62
		T1	3.84±0.15	8.59±0.32	12.93±0.45	16.65±0.56	19.57±0.65
		T2	3.18±0.15	6.36±0.33	10.69±0.46	14.04±0.56	16.86±0.66
		T3	3.01±0.15	6.63±0.33	10.48±0.46	13.62±0.57	16.20±0.67
		p	0.000	0.000	0.000	0.000	0.000

Notes: The values in the table are the transformed values obtained from the analysis of covariance.

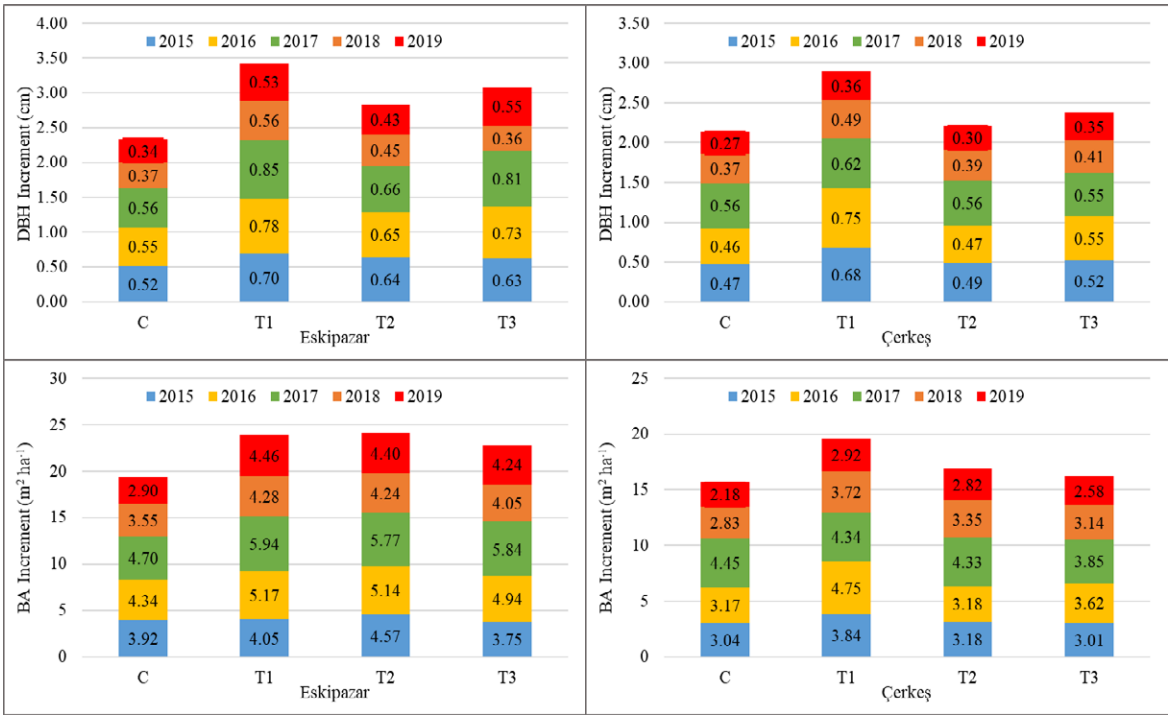

Figure 2 Increments of DBH and BA for each measurement year.

To determine whether there were statistically significant differences in growth parameters based on PCT intensities, an analysis of covariance (ANCOVA) was conducted (Table 4). The analysis revealed that, for both the Eskipazar and Çerkeş plots, statistically significant differences in DBH and BA increments were found between the different PCT intensities each year at a 99% confidence level.

The increment values for height and total volume, which are stand growth variables, based on PCT and measurement years are presented in Table 5. In the Eskipazar plot, the 5-year height increments were found to be 1.68 m in the control plot, 1.97 m in the T2 plot, 2.23 m in the T3 plot, and 2.27 m in the T1 plot. Similarly, in the Çerkeş plot, the highest height increment was recorded in the T1 treatment, with a value of 2.10 m. As the results indicate, height values increased in correlation with the increase in PCT intensity. In terms of total volume increment, the

Table 5 Increments of H and V regarding PCT intensities and years of measurements.

Plot	Variable	PCT intensity	Increment by years			
			2014-2015	2014-2016	2014-2018	2014-2019
Eskipazar	H (m)	C	0.33±0.01	0.72±0.01	1.36±0.03	1.68± 0.04
		T1	0.41±0.01	0.85±0.02	1.72±0.04	2.27± 0.05
		T2	0.37±0.01	0.79±0.02	1.56±0.04	1.97± 0.05
		T3	0.42±0.01	0.87±0.02	1.71±0.05	2.23± 0.05
		p	0.000	0.000	0.000	0.000
	V (m^3/ha)	C	16.60±0.43	37.11±1.06	77.73±2.31	95.54±2.79
		T1	17.87±0.50	42.09±1.22	93.75±2.65	121.23±3.20
		T2	19.18±0.44	42.75±1.07	93.43±2.32	119.83±2.81
		T3	16.84±0.51	40.11±1.24	90.47±2.70	117.60±3.26
		p	0.000	0.000	0.000	0.000
Çerkeş	H (m)	C	0.32±0.01	0.66±0.02	1.32±0.05	1.76±0.06
		T1	0.37±0.01	0.78±0.02	1.56±0.06	2.10±0.06
		T2	0.34±0.01	0.72±0.02	1.33±0.05	1.75±0.06
		T3	0.36±0.01	0.77±0.02	1.46±0.05	1.90±0.05
		p	0.026	0.001	0.002	0.003
	V (m^3/ha)	C	13.40±0.53	28.86±1.27	67.03±2.36	84.09±2.92
		T1	17.47±0.56	40.32±1.33	82.09±2.49	101.56±3.08
		T2	13.65±0.58	28.75±1.38	66.73±2.57	85.50±3.17
		T3	14.01±0.58	32.02±1.37	68.80±2.56	86.46±3.16
		p	0.000	0.000	0.000	0.000

Notes: The values in the table are the transformed values obtained from the analysis of covariance

lowest values were observed in the control plot in both the Eskipazar and Çerkeş plots (95.54 m^3/ha and 84.09 m^3/ha , respectively), while the highest values were found in the T1 treatment (121.23 m^3/ha and 101.56 m^3/ha , respectively).

The analysis of covariance conducted to test the significant differences in growth variables based on PCT intensity (Table 5) revealed that there were statistically significant differences in height and total volume increments across different PCT intensities during all measurement periods. Bonferroni t-test was conducted to determine the statistical significance of the differences between various PCT treatments based on the increments of the measured parameters. (Tables 6 and 7). By the end of the fifth growing season, it was found that in the Eskipazar plot, the differences in DBH values between all PCT treatments were statistically significant, whereas in the Çerkeş plot, the differences between T2 and C, T3 and C, and T2 and T3 treatments were not significant. For BA increments, all differences between the PCT treatments and the control plots in the Eskipazar plot were statistically significant. In the Çerkeş plot, significant differences were found between T1 and C, T1 andT2, and T1 and T3 treatments (Table 6).

Table 6 Bonferroni's t-test results concerning the increments of DBH and BA.

Increment year	PCT levels	Difference of mean increment							
		Eskipazar				Çerkeş			
		DBH	*P*	BA	*P*	DBH	*P*	BA	*P*
2014–2015	T1 – C	0.168	**	0.129	ns	0.207	**	0.800	**
	T2 – C	0.110	**	0.645	**	0.028	ns	0.140	ns
	T3 – C	0.095	**	-0.172	ns	0.059	ns	-0.035	ns
	T1 – T2	0.058	*	-0.517	*	0.179	**	0.660	*
	T1 – T3	0.072	**	0.301	ns	0.148	**	0.835	**
	T2 – T3	0.014	ns	0.817	**	-0.031	ns	0.175	ns
2014–2016	T1 – C	0.389	**	0.957	ns	0.454	**	2.374	**
	T2 – C	0.203	**	1.447	**	0.008	ns	0.146	ns
	T3 – C	0.254	**	0.432	ns	0.135	ns	0.419	ns
	T1 – T2	0.186	**	-0.490	ns	0.445	**	2.228	**
	T1 – T3	0.135	*	0.525	ns	0.319	**	1.956	**
	T2 – T3	-0.051	ns	1.015	ns	-0.127	ns	-0.273	ns
2014–2017	T1 – C	0.684	**	2.190	*	0.538	**	2.268	**
	T2 – C	0.318	**	2.514	**	0.015	ns	0.031	ns
	T3 – C	0.507	**	1.569	ns	0.136	*	-0.184	ns
	T1 – T2	0.367	**	-0.324	ns	0.523	**	2.237	**
	T1 – T3	0.177	ns	0.622	ns	0.402	**	2.452	**
	T2 – T3	-0.189	*	0.946	ns	-0.121	ns	-0.215	ns
2014–2018	T1 – C	0.878	**	2.937	**	0.679	**	3.166	**
	T2 – C	0.414	**	3.209	**	0.054	ns	0.555	ns
	T3 – C	0.650	**	2.071	ns	0.193	ns	0.131	ns
	T1 – T2	0.464	**	-0.272	ns	0.625	**	2.611	**
	T1 – T3	0.228	*	0.866	ns	0.485	**	3.035	**
	T2 – T3	-0.236	**	1.138	ns	-0.139	ns	0.424	ns
2014–2019	T1 – C	1.087	**	4.486	**	0.781	**	3.902	**
	T2 – C	-0.535	**	4.712	**	0.099	ns	1.190	ns
	T3 – C	-0.823	**	3.415	**	0.275	*	0.528	ns
	T1 – T2	0.551	**	-0.226	ns	0.682	**	2.712	*
	T1 – T3	0.264	*	1.071	ns	0.506	**	3.374	**
	T2 – T3	-0.287	**	1.297	ns	-0.176	ns	0.662	ns

*$p < 0.05$; **$p < 0.01$; ns: not significant

The Bonferroni t-test results for height and total volume values in Table 7 indicate that, by the end of the five-year growth period, the only statistically significant differences in height for the Çerkeş plot were between T1 and C and T1 and T2 treatments, while in the Eskipazar plot, only the differences between T1 and T3 treatments were not statistically significant. In terms of total volume, the results showed that in the Eskipazar plot, the differences between the control and all intervention treatments were statistically significant at a 99% confidence level by the fifth growing season. In the Çerkeş plot, significant differences were found between T1 and C, T1 and T2, and T1 and T3 treatments.

Table 7 Bonferroni's t-test results concerning the increments of H and V.

Increment year	PCT levels	Difference of mean increment							
		Eskipazar				Çerkeş			
		H	*P*	V	*P*	H	*P*	V	*P*
2014–2015	T1 – C	0.078	**	1.268	ns	0.044	ns	4.074	**
	T2 – C	0.041	*	2.578	**	0.018	ns	0.259	ns
	T3 – C	0.090	**	0.231	ns	0.041	*	0.610	ns
	T1 – T2	0.037	ns	-1.310	ns	0.026	ns	3.815	**
	T1 – T3	-0.012	ns	1.037	ns	0.003	ns	3.464	**
	T2 – T3	-0.049	**	2.347	**	-0.023	ns	-0.351	ns
2014–2016	T1 – C	0.129	**	4.980	*	0.104	**	11.469	**
	T2 – C	0.080	*	5.645	**	0.051	ns	-0.101	ns
	T3 – C	0.153	**	3.007	ns	0.102	**	3.166	ns
	T1 – T2	0.049	ns	-0.665	ns	0.053	ns	11.570	**
	T1 – T3	-0.024	ns	1.973	ns	0.002	ns	8.303	**
	T2 – T3	-0.073	*	2.638	ns	-0.051	ns	-3.267	ns
2014–2018	T1 – C	0.381	**	16.020	**	0.266	**	15.058	**
	T2 – C	0.217	**	15.702	**	0.038	ns	-0.300	ns
	T3 – C	0.368	**	12.739	**	0.143	ns	1.763	ns
	T1 – T2	0.163	*	0.319	ns	0.227	**	15.357	**
	T1 – T3	0.013	ns	3.282	ns	0.123	ns	13.294	**
	T2 – T3	-0.151	ns	2.963	ns	-0.105	ns	-2.063	ns
2014–2019	T1 – C	0.616	**	25.696	**	0.294	**	17.469	**
	T2 – C	0.302	**	24.293	**	0.034	ns	1.406	ns
	T3 – C	0.566	**	22.064	**	0.143	ns	2.367	ns
	T1 – T2	0.314	**	1.404	ns	0.260	**	16.063	**
	T1 – T3	0.050	ns	3.632	ns	0.151	ns	15.102	**
	T2 – T3	-0.264	**	2.228	ns	-0.109	ns	-0.961	ns

*$p < 0.05$; **$p < 0.01$; ns: not significant

DISCUSSION

PCT is a crucial silvicultural intervention applied to manage stand structure and promote individual tree growth at an early stage (Smith 1986, Özdemir et al. 1987, Fahlvik et al. 2018). This practice is used to alter stand structure by allocating growth resources to the selected stems. The growth response of the stand after PCT varies depending on several factors, such as the timing of the intervention, stand age, density levels, biological characteristics of the species, and local climate conditions (Pitt and Lanteigne 2008, Holmström et al. 2016, Bjelanovic et al. 2021). Studies have shown that PCT intensity levels have statistically significant effects on increases in height, diameter, total volume and total basal area (Ginn et al. 1991, Simard et al. 2004, Yılmaz et al. 2010).

In this study, which investigated the effect of PCT treatments on the development of natural Scots pine stands at the thicket stage, it was found that the thinning treatments applied at varying intensities in both plots had a statistically significant effect on the average diameter increment. Following the thinning interventions applied after the 2014 growing season, significant differences were observed in the average diameter increment across all treatments at the end of the fifth growing season (2019). The lowest diameter increment was observed in the control treatment (2.34 cm in the Eskipazar plot and 2.13 cm in the Çerkeş plot), while the highest diameter increment was recorded in the traditional treatment (3.42 cm in the Eskipazar plot and 2.90 cm in the Çerkeş plot). It was also observed that the average diameter increments increased as the thinning intensity increased in the plots. Similarly, Öncül et al. (2016) found that thinning in natural Scots pine stands resulted in the lowest diameter increment in the control treatment (5.34 cm) and the highest in the heavy intervention treatment (6.64 cm) after three years, also noting that diameter increments increased with greater thinning intensity. Ulvcrona et al. (2007) highlighted that DBH values increased in Scots pine stands in relation to the intensity and timing of PCT. Similarly, diameter growth increased with the intensity of PCT in *P. sylvestris* (Mäkinen and Isomäki 2004). In a similar study by Bataineh et al. (2013) on *Abies balsamea* (L.) Mill. and *Picea rubens* Sarg. stands, diameter growth 13 to 24 years after PCT was higher in the thinned plots (3.9 cm) compared to the control plots (3.1 cm). Pitt and Lanteigne (2008) investigated how growth parameters in *P. rubens* and *A. balsamea* stands 42–44 years after PCT were affected by varying PCT intensities (spacing of 1.2 m, 1.8 m, and 2.4 m). They found that average diameters rose in response to greater PCT intensities. Numerous studies have reported increased diameter growth due to decreased stem density following thinning (Miller 2000, Varmola and Salminen 2004, Linkevičius et al. 2014, Bayar and Deligöz 2019, Deligöz et al. 2022).

The primary reason for the increase in diameter growth after thinning interventions is that the remaining trees utilize available resources more efficiently due to the reduction in tree density. This allows the remaining individuals to access more light, water, and nutrients, which consequently enhances photosynthesis (Goudiaby et al. 2011). Makineci (2005) also highlighted in his study that diameter growth increases in thinned areas as a result of higher soil moisture and reduced root competition, since fewer individuals can benefit from a larger soil volume. Wider spacing is associated with greater diameter growth (Ferguson et al. 2011).

The impact of PCT on tree height can differ based on factors such as PCT intensity levels, timing of the intervention, tree species, and regional biological characteristics. This study found that over the five-year growth period, there were notable differences in height increments due to varying PCT intensities. It was determined that as the intensity of the PCT intervention increased, tree height also increased. Similarly, average tree heights in PCT plots were found to be greater than those in the control plots in *P. sylvestris* stands (Sıvacıoğlu et al. 2006). Weiskittel et al. (2009) reported that in *A. balsamea* and *P. rubens* stands, height growth, crown ratio, and crown width increased significantly within 25 years following PCT compared to control plots. In Scots pine stands, average tree heights after various levels of PCT ranged between 1.2 and 8.3 meters (Fahlvik et al. 2005). According to Zhang et al. (2006), *Pinus banksiana* Lamb. height increments were lowest in the control plots and largest with heavy PCT treatments. Brissette et al. (1999) determined that, 18 years after thinning, trees in the treated plots were 32% taller than those in the control plots. Other studies have shown that the effects of PCT can vary between species. For instance, according to research by Zhang et al. (2009) on *A. balsamea* stands, PCT plots showed less height increases than the control plots. Additionally, no significant effect of PCT on height growth was found in *Pinus contorta* var. *latifolia* Engelm. stands (Lindgren and Sullivan 2013). Kaymakçı et al. (2000) noted that delayed PCT had no effect on increasing height growth in *Pinus nigra* J.F.Arnold stands but limited diameter expansion. Research on other tree species indicated that different PCT intensities have no discernible effect on height growth (Pinkard and Neilsen 2003, Simard et al. 2004, Rytter and Stener 2005, Rytter 2013).

Among the most important markers of stand growth are total basal area and volume. In both study plots, the effect of thinning treatments on total basal area and volume per hectare was found to be statistically significant during each growth period, with the highest basal area increments in the Eskipazar plot recorded in the T2 treatment and in the Çerkeş plot in the T1 treatment. The highest total volume increments were also observed in the T1 treatment in both plots. One of the key findings of this study was the declining trend in growth increments after the third growing season, particularly evident in DBH and volume metrics. This trend suggests that the benefits of a single PCT intervention may diminish over time, necessitating a follow-up intervention within 3–5 years to sustain growth momentum. These observations support a rotation-based thinning regime rather than a one-time intervention, a recommendation echoed by Varmola and Salminen (2004) in similar studies on Scots pine in Nordic regions. Similar to the findings of this study, Ruha and Varmola (1997) noted that PCT significantly increased diameter and volume increments during the second decade in young Scots pine stands. Another study on *P. banksiana* stands showed that intensive thinning (2.13 m spacing or 2,212 stems/ha) increased tree diameter by more than 20% and stem volume per tree by more than 75% as compared to the control (Zhang et al. 2006). Conversely, other studies have reported decreases in total volume and basal area with increasing PCT intensity (Simard et al. 2004, Bayar and Deligöz 2020). For instance, in a study on *Picea abies* (L.) H.Karst. and *P. sylvestris* stands, while diameter growth increased with a reduction in tree density, total volume decreased after PCT interventions (Pettersson 1993). According to Pothier (2002) study on *A. balsamea* stands, the PCT intensity of 2,000 trees/ha produced the highest total volume with DBH greater than 15 cm, while the PCT intensity of 15,000 trees/ha produced the highest total volume with DBH greater than 1.1 cm. Another study reported that heavy PCT resulted in a volume loss of over 20% after 20 years in young *P. abies* stands (Sterba 2003). Furthermore, another study that looked at how different PCT levels affected *A. balsamea* and *P. rubens* stands found that the 1.8 m spacing treatment had the largest total basal area and stand volume (Pitt and Lanteigne 2008). Despite a significant diameter increase after PCT, the overall basal area of *Picea mariana* Britton, Sterns et Poggenb. declined 20 years after the intervention, according to research by Wotherspoon et al. (2020). However, despite an initial reduction in the basal area after thinning, in later years, total basal area in thinned plots surpassed that in control plots due to greater diameter growth. It was noted that the greater diameter development at the time of intervention made up for the decrease in basal area (Sıvacıoğlu et al. 2006).

Although both experimental sites shared similar stand ages and soil texture classifications, site-specific differences such as total precipitation, litter biomass, and soil pH may have contributed to the variations in growth responses across treatments. The Eskipazar and Çerkeş plots differed in several key ecological parameters, including litter biomass, soil pH, and annual precipitation. For instance, the higher litter accumulation in Eskipazar

(41.05 t/ha vs. 27.97 t/ha) may have enhanced nutrient cycling and microbial activity, potentially leading to more favorable growth conditions in denser treatments such as T2. Moreover, the more acidic soil pH in Eskipazar (5.27 vs. 5.92) could have influenced nutrient availability, particularly for elements like nitrogen and phosphorus, which play a critical role in early-stage growth. The 119 mm difference in annual precipitation between the two sites also may have affected water availability and root competition dynamics, especially in more intensively thinned plots. These findings underscore the need to consider site-specific edaphoclimatic factors when formulating thinning prescriptions and extrapolating growth models across regions.

CONCLUSIONS

This study demonstrated that site-specific edaphoclimatic factors, particularly litter biomass, soil pH, and annual precipitation significantly influenced the growth responses of Scots pine to precommercial thinning (PCT). Improved growth performance in denser treatments in Eskipazar, characterized by higher litter accumulation and more acidic soils, emphasizes the need to tailor thinning strategies to local site conditions when applying growth models across different regions.

The findings also provide important guidance on optimal thinning intensity. In natural Scots pine stands in Türkiye, maintaining approximately 3000–3500 stems per hectare appears to achieve the most favorable outcomes in terms of diameter, height, basal area, and total volume. Notably, while Scandinavian thinning recommendations generally suggest retaining 2000–2500 stems per hectare depending on site productivity (Parvianen 1978, Ruha and Varmola 1997, Varmola and Salminen 2004), results from this study suggest that slightly higher densities may be preferable in natural stands in Türkiye to optimize growth.

Furthermore, the observed trend of increasing growth increments during the initial three years, followed by a decline in the subsequent years, suggests that a thinning interval of approximately 3–5 years may be beneficial for maintaining stand vigor and productivity, especially in fast-growing stands. However, this interval may vary depending on site quality and growth rates. In addition, careful consideration should be given to the protection of residual trees, particularly in heavily thinned plots, to mitigate risks from wind and snow damage. Conversely, neglecting timely PCT interventions may increase the likelihood of damage caused by snow pressure and competition stress, especially in high-elevation sites. Finally, the selection of future crop trees should prioritize individuals with superior form and vitality, characterized by symmetrical crowns, slender branches, straight stems, and the absence of permanent defects.

ACKNOWLEDGMENT

This article was prepared using data from the project titled "Effects of Initial Thinning in Natural Scots Pine (*Pinus sylvestris* L.) Stands in the Ankara Regional Directorate of Forestry," which was initiated under the coordination of the Central Anatolia Forestry Research Institute Directorate.

REFERENCES

- Achim, A., J.C. Ruel, B.A. Gardiner, 2005: Evaluating the effect of precommercial thinning on the resistance of balsam fir to windthrow through experimentation, modelling, and development of simple indices. Canadian Journal of Forest Research 35: 1844–1853. https://doi.org/10.1139/x05-130
- Atar, F., 2022: Eight-year results of precommercial thinning on growth parameters in *Picea orientalis* (L.) link stands. Scandinavian Journal of Forest Research, 37 (5–8): 330–337. https://doi.org/10.1080/02827581.2022.2117410
- Bataineh, M.M., R.G. Wagner, A.R. Weiskittel, 2013: Long-term response of spruce-fir stands to herbicide and precommercial thinning: observed and projected growth, yield, and financial returns in central Maine, USA. Canadian Journal of Forest Research 43 (999): 385–395. https://doi.org/10.1139/cjfr-2012-0343
- Bayar, E., O. Alkan, 2023: Kızılçam (*Pinus brutia* Ten.) meşcerelerinde uygulanan ilk aralama çalışmalarının değerlendirilmesi: Sütçüler örneği. Turkish Journal of Forestry 24 (1): 11–17. https://doi.org/10.18182/tjf.1228928
- Bayar, E., A. Deligöz, 2019: Three-year results of precommercial thinning in Burdur region natural Anatolian black pine stand. Artvin Coruh University Journal of Forestry Faculty 20 (1): 18–27.
- Bayar, E., A. Deligoz, 2020: Effects of precommercial thinning on growth parameters in *Pinus nigra* Arn. subsp. *pallasiana* (Lamb.) Holmboe stand. Journal of Forestry Research 31: 1803–1811. https://doi.org/10.1007/s11676-019-00992-z
- Bjelanovic, I., P. Comeau, S. Meredith, B. Roth, 2021: Precommercial thinning increases spruce yields in boreal mixedwoods in Alberta, Canada. Forests 12 (4): 412. https://doi.org/10.3390/f12040412
- Boratynski, A., 1991: Range of natural distribution. In (Giertych, M., C. Matyas, eds.): Genetics of Scots pine. Elsevier Publication, Amsterdam.
- Brissette, J., R.M. Frank Jr, T.L. Stone, T.A. Skratt, 1999: Precommercial thinning in a northern conifer stand: 18-year results. Forestry Chronicle 75: 967–972.
- Caudullo, G., E. Welk, J. San-Miguel-Ayanz, 2017: Chorological maps for the main European woody species. Data in Brief 12: 662–666. https://doi.org/10.1016/j.dib.2017.05.007
- Chase, C.W., M.J. Kimsey, T.M. Shaw, M.D. Coleman, 2016: The response of light, water, and nutrient availability top re-commercial thinning in dry inland Douglas-fir forests. Forest Ecology and Management 363: 98–109. https://doi.org/10.1016/j.foreco.2015.12.014
- Danusevicius, D., V. Kerpauskaite, D. Kavaliauskas, B. Fussi, M. Konnert, V. Baliuckas, 2016: The effect of tending and commercial thinning on the genetic diversity of Scots pine stands. European Journal of Forest Research 135 (6): 1159–1174. https://doi.org/10.1007/s10342-016-1002-7
- Deligöz, A., E. Bayar, M. Genç, Y. Karatepe, 2022: Response of *Pinus nigra* subsp. *pallasiana* to precommercial thinning in a humid region under the oro-Mediterranean climatic conditions. Forestist 72 (2): 175–182. https://doi.org/ 10.5152/forestist.2021.21022
- Egnell, G., K.A. Ulvcrona, 2015: Stand productivity following whole-tree harvesting in early thinning of Scots pine stands in Sweden. Forest Ecology and Management 340: 40–45. https://doi.org/10.1016/j.foreco.2014.12.017

- Eler, Ü., R. Özçelik, İ. Özdemir, Y. Çatal, 2004: Effects of delayedrelease cutting on the development of two young natural Taurus cedar (*Cedrus libani* A. Rich.) stands in the lakes district. Süleyman Demirel University Journal of Natural and Applied Sciences 8 (1): 1–6.
- Fahlvik, N., M. Berglund, H. Holmström, U. Nilsson, 2018: Simulation of the long-term effects of different strategies for precommercial thinning in *Pinus sylvestris*. Scandinavian Journal of Forest Research 33 (4): 347–356. https://doi.org/10.1080/02827581.2017.1383508
- Fahlvik, N., P.M. Ekö, N. Pettersson, 2005: Influence of precommercial thinning grade on branch diameter and crown ratio in *Pinus sylvestris* in southern Sweden. Scandinavian Journal of Forest Research 20 (3): 243–251. https://doi.org/10.1080/02827580510008266
- Ferguson, D.E., J.C. Byrne, W.R. Wykoff, B. Kummet, T. Hensold, 2011: Response of ponderosa pine stands to pre-commercial thinning on Nez Perce and Spokane Tribal forests in the Inland Northwest, Res. Pap. RMRS-RP-88. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, USA.
- Fick, S.E., R.J. Hijmans, 2017: WorldClim 2: new 1-km spatial resolution climate surfaces for global land areas. International Journal of Climatology 37 (12): 4302–4315. https://doi.org/10.1002/joc.5086
- Fleming, R.L., 1994: RPF-II proposal-management of black spruce on highly productive sites. Unpubl. rep. Forestry Canada, Sault Ste. Marie, ON, Canada.
- Frda, 1996: Field guidelines for the selection of stands for spacing (coastal). Can.–B.C. Partnership Agreement For. Resource Dev.: FRDA II. B.C. Ministry of Forests Press, pp. 5–12.
- Ginn, S.E., J.R. Seiler, B.H. Cazell, R.E. Kreh, 1991: Physiological and growth responses of eight-year-old loblolly pine stands to thinning. Forest Science 37: 1030–1040. https://doi.org/10.1093/forestscience/37.4.1030
- Goudiaby, V., S. Brais, Y. Grenier, F. Berninger, 2011: Thinning effects on jack pine and black spruce photosynthesis in easternboreal forests of Canada. Silva Fennica 45 (4): 595–609. https://doi.org/10.14214/sf.95
- Guner, S., A. Tufekcioglu, N. Celik, 2017: Effects of thinning, liming, and nitrogen application on the growth of a young oriental beech (*Fagus orientalis* Lipsky) forest stand. Fresenius Environmental Bulletin 26 (11): 6727–6733.
- Güney, D., F. Atar, İ. Turna, A. Bayraktar, A. Gunlu, 2021: Influence of precommercial thinning on growth parameters in *Fraxinus angustifolia* Vahl plantations. Turkish Journal of Forest Science 5 (2): 339–351.
- Güney, D., F. Atar, I. Turna, A. Günlü, 2022: Effects of precommercial thinning intensity on growth of *Fagus orientalis* Lipsky stands over 6 years. Journal of Forestry Research 33: 937–947. https://doi.org/10.1007/s11676-021-01396-8
- Holmström, E., K. Hjelm, U. Johansson, M. Karlsson, S. Valkonen, U. Nilsson, 2016: Pre-commercial thinning, birch admixture and sprout management in planted Norway spruce stands in South Sweden. Scandinavian Journal of Forest Research 31 (1): 56–65. https://doi.org/10.1080/02827581.2015.1055792
- Huuskonen, S., J. Hynymen, 2006: Timing and intensity of precommercial thinning and their on the first commercial thinning in Scots pine stands. Silva Fennica 40 (4): 645–662. https://doi.org/10.14214/sf.320
- Karlsson, L., U. Bergsten, T. Ulvcrona, B. Elfving, 2013: Long-term effects on growth and yield of corridor thinning in young *Pinus sylvestris* stands. Scandinavian Journal of Forest Research 28 (1): 28–37. https://doi.org/10.1080/02827581.2012.702222
- Kayacık, H., 1963: Türkiye çamları ve bunların coğrafi yayılışları üzerine araştırmalar. İ.Ü. Orman Fakültesi Dergisi Seri A 13: 1–17.
- Kaymakçı, E., Ö.S. Erkuloğlu, A.F. Eronat, 2000: Research on delayed thinning of *Pinus nigra* in Gördes state forest enterprise. Ege Forestry Research Press, pp. 4–6.
- Klädtke, J., 2001: Konzepte zur Buchen-Lichtwuchsdurchforstung. AFZ/Der Wald 56: 1047–1050.
- Koga, S., S.Y. Zhang, J. Begin, 2002: Effects of precommercial thinning on annual radial growth and wood density in balsam fir (*Abies balsamea*). Wood and Fiber Science 34: 625–642.
- Leclerc, M.E., V. Griess, B. Eskelson, S. Simard, G. Harger, 2020: Effects of precommercial thinning on growth and diversity of paper birch leading stands 25 years following thinning. Prov. B.C. Victoria, B.C. Exten. Note 123: 1–7. https://dx.doi.org/10.14288/1.0392650
- Lindgren, P.M.F., T.P. Sullivan, 2013: Long-term responses of tree and stand growth of young lodgepole pine to precommercial thinning and repeated fertilization. Forest Ecology and Management 307: 155–164. https://doi.org/10.1016/j.foreco.2013.06.058
- Linkevičius, E., A. Kuliešis, H. Röhle, J. Schröder, M. Aleinikovas, 2014: The impact of competition for growing space on diameter, basal area and height growth in pine trees. Baltic Forestry 20 (2): 301–313.
- Makineci, E., 2005: Sapsız meşe (*Quercus petraea* (Matlusch) Lieb.) baltalık ormanında aralamaların çap artımı ve bazı toprak özelliklerine etkileri. Süleyman Demirel Üniversitesi Orman Fakültesi Dergisi A (2): 1–10.
- Mäkinen, H., A. Isomäki, 2004: Thinning intensity and long-term changes in increment and stem form of Norway spruce trees. Forest Ecology and Management 201 (2–3): 295–309. https://doi.org/10.1016/j.foreco.2004.07.017
- Miller, G.W., 2000: Effect of crown growing space on the development of young hardwood crop trees. Northern Journal of Applied Forestry 17: 25–35. https://doi.org/10.1093/njaf/17.1.25
- Niemistö, P., S. Valkonen, 2021: Growth response to thinning in two-storied mixed stands of Scots pine and Norway spruce. Scandinavian Journal of Forest Research 36 (6): 448–459. https://doi.org/10.1080/02827581.2021.1961017
- Nutto, L., P. Spathelf, R. Rogers, 2005: Managing diameter growth and natural pruning of Parana pine, *Araucaria angustifolia* (Bert.) O Ktze., to produce high value timber. Annals of Forest Science 62: 163–173. https://doi.org/10.1051/forest:2005008
- Oker-Blom, P., S. Kellomaki, E. Valtonen, H. Väisänen, 1988: Structural development of *Pinus sylvestris* stands with varying initial density: a simulation model. Scandinavian Journal of Forest Research 3 (1–4): 185–200. https://doi.org/10.1080/02827588809382508
- Öncül, Ö., C. Uğurlu¸ M. Köse, F. Tilki, 2016: Effects of precommercial thinning on stem diameter and basal area in natural stands of Scots pine (*Pinus sylvestris* L.). Journal of Forestry Research 1 (3): 29–37.
- Özdamar, K., 2013: SPSS ile Biyoistatistik. 9. baskı, Nisan Kitapevi, Eskişehir, Turkiye.
- Özdemir, T., Ü. Eler, U. Şırlak, 1987: Effects of release cutting for natural *Pinus brutia* Ten. stands in Antalya forest region. For. Res. Inst. 184: 1–31.
- Özel, H.B., M. Ertekin, 2010: Bartın ve Devrek Yöreleri Doğu kayını (*Fagus orientalis* Lipsky.) Doğal Grup Gençleştirme Alanlarındaki Ekolojik Koşullar. Bartın Orman Fakültesi Dergisi 12 (17): 47–64.

- Parviainen, J., 1978: Taimisto- ja riukuvaiheen mannnikön harvennus. Referat: Durchforstung im Kiefernbestand in der Jungwuchs- und Stangenholzphase. Folia Forestalia 346: 1–40.
- Pettersson, N., 1993: The effect of density after precommercial thinning on volume and structure in *Pinus sylvestris* and *Picea abies* stands. Scandinavian Journal of Forest Research 8: 528–539. https://doi.org/10.1080/02827589309382799
- Pinkard, E.A., W.A. Neilsen, 2003: Crown and stand characteristics of *Eucalyptus nitens* in response to initial spacing: implications for thinning. Forest Ecology and Management 172: 215–227. https://doi.org/10.1016/S0378-1127(01)00803-9
- Pitt, D., L. Lanteigne, 2008: Long-term outcome of precommercial thinning in northwestern New Brunswick: Growth and yield of balsam fir and red spruce. Canadian Journal of Forest Research 38: 592–610. https://doi.org/10.1139/X07-132
- Pothier, D., 2002: Twenty-year results of precommercial thinning in a balsam fir stand. Forest Ecology and Management 168: 177–186. https://doi.org/10.1016/S0378-1127(01)00738-1
- Pravdin, L.H., 1969: Scots pine variation, intraspecific taxonomy and selection. USDA Forest Service, Washington D.C.
- Prévost, M., M.M. Gauthier, 2012: Precommercial thinning increases growth of overstory aspen and understory balsam fir in a boreal mixedwood stand. Forest Ecology and Management 278: 17–26. https://doi.org/10.1016/j.foreco.2012.05.005
- Reventlow, D.O.J., T. Nord-Larsen, J.P. Skovsgaard, 2019: Pre-commercial thinning in naturally regenerated stands of European beech (*Fagus sylvatica* L.): effects of thinning pattern, stand density and pruning on tree growth and stem quality. Forestry 92 (1): 120–132. https://doi.org/10.1093/forestry/cpy039
- Rice, J.A., G.B. MacDonald, D.H. Weingartner, 2001: Precommercial thinning of trembling aspen in northern Ontario: Part 1 – Growth responses. The Forestry Chronicle 77: 893–901. https://doi.org/10.5558/tfc77893-5
- Ruha, T., M. Varmola, 1997: Precommercial thinning in naturally regenerated Scots pine stands in northern Finland. Silva Fennica 31: 401–415. https://doi.org/10.14214/sf.a8537
- Rytter, L., 2013: Growth dynamics of hardwood stands during the precommercial thinning phase – Recovery of retained stems after competition release. Forest Ecology and Management 302: 264–272. https://doi.org/10.1016/j.foreco.2013.03.034
- Rytter, L., L. Stener, 2005: Productivity and thinning effects in hybrid aspen (*Populus tremula* L. × *P. tremuloides* Michx.) stands in southern Sweden. Forestry 78: 285–295. https://doi.org/10.1093/forestry/cpi026
- Saatçioğlu, F., 1976: Silvikültür I. Silvikültürün Biyolojik Esasları ve Prensipleri. İ.Ü. Orman Fak. Yayınları, Yayın No 2187/222, İstanbul.
- Sıvacıoğlu, A., A. Durkaya, H. Vurdu, R. Benli, 2006: Effects of the release cuttings on increment and growth of the natural Scots pine (*Pinus sylvestris* L.) stands in Taşköprü (Kastamonu) region. Gazi Univ. J. For. Fac. 6 (2): 153–166.
- Simard, S.W., T. Blenner-Hassett, I.R. Cameron, 2004: Pre-commercial thinning effects on growth, yield and mortality in even-aged paper birch stands in Biritish Columbia. Forest Ecology and Management 190: 163–178. https://doi.org/10.1016/j.foreco.2003.09.010
- Skovsgaard, J.P., 2009: Analysing effects of thinning on stand volume growth in relation to site conditions: a case study for even-aged Sitka spruce (*Picea sitchensis* (Bong.) Carr.). Forestry 82 (1): 87–104. https://doi.org/10.1093/forestry/cpn047
- Smith, D.M., 1986: The practice of silviculture, 8th ed. John Wiley and Sons Toronto, ON, Canada.
- Splawinski, T.B., I. Drobyshev, S. Gauthier, Y. Bergeron, D.F. Greene, N. Thiffault, 2017: Precommercial thinning of *Picea mariana* and *Pinus banksiana*: impact of treatment timing and competitors on growth response. Forest Science 63 (1): 62–70. https://doi.org/10.5849/forsci.15-178
- Sterba, H., 2003: Growth after biomass removal during precommercial thinning. In (Limbeck-Lilneau, B., T. Steinmüller, K. Stampfer, eds.): Austro2003: High tech forest operations for mountainous terrain, Shlägl, Austria, October 5–9, 2003, pp. 1–9.
- Şenyurt, M., 2011: Batı Karadeniz Yöresi Sarıçam Meşcerelerinde Artım ve Büyüme. Doktora Tezi, İstanbul Üniversitesi Fen Bilimleri Enstitüsü, İstanbul.
- Thibodeau, L., P. Raymond, C. Camiré, A.D. Munson, 2000: Impact of precommercial thinning in balsam fir stands on soil nitrogen dynamics, microbial biomass, decomposition, and foliar nutrition. Canadian Journal of Forest Research 30: 229–238. https://doi.org/10.1139/x99-202
- Tufekcioglu, A., S. Guner, F. Tilki, 2005: Thinning effects on production, root biomass and some soil properties in a young oriental beech stand in Artvin, Turkey. Journal of Environmental Biology 26 (1): 91–95.
- Turna, İ., M.G. Sertkaya, F. Atar, 2017: Evaluation of the combating against chestnut blight (*Cryphonectria parasitica*) in terms of silviculture: The sample of Kütahya Simav. Turkish Journal of Forestry 18 (3): 187–196.
- Turna, İ., 2003: Variation of some morphological and electrophoretic characters of 11 populations of Scots pine in Turkey. Israel Journal of Plant Sciences 51: 223–230. https://doi.org/10.1560/M4RX-QBGM-JVYQ-74B8
- Ulvcrona, K.A., S. Claesson, K. Sahlén, T. Lundmark, 2007: The effects of timing of pre-commercial thinning and stand density on stem form and branch characteristics of *Pinus sylvestris*. Forestry 80 (3): 323–335. https://doi.org/10.1093/forestry/cpm011
- Varmola, M., H. Salminen, 2004: Timing and intensity of precommercial thinning in *Pinus sylvestris* stands. Scandinavian Journal of Forest Research 19: 142–151. https://doi.org/10.1080/02827580310019545
- Wallentin, C., U. Nilsson, 2011: Initial effect of thinning on stand gross stem-volume production in a 33-year-old Norway spruce (*Picea abies* (L.) Karst.) stand in Southern Sweden. Scandinavian Journal of Forest Research 26 (S11): 21–35. https://doi.org/10.1080/02827581.2011.564395
- Weiskittel, A.R., L.S. Kenefic, R.S. Seymour, L.M. Phillips, 2009: Long-term effects of precommercial thinning on the stem dimensions, form and branch characteristics of red spruce and balsam fir crop trees in Maine, USA. Silva Fennica 43 (3): 397–409. https://doi.org/10.14214/sf.196
- Wotherspoon, A., R.L. Bradley, D. Houle, S. Tremblay, M. Barrette, K. Reicis, 2020: Mechanisms by which pre-commercial thinning increases black spruce growth in different climates and soil types. Forests 11 (5): 599. https://doi.org/10.3390/f11050599
- Yılmaz, E., A. Çalışkan, Ü. Alptekin, S. Tüfekçi, F. Aytar, H. Keles, A. Yıldızbakan, 2010: Determination of release cutting treatments for Taurus (Lebanon) cedar (*Cedrus libani* A. Rich.) stands at the thicket stage. Eastern Mediterranean Forestry Research Institute Press, pp. 56–63.
- Zeide, B., 2001: Thinning and growth: a full turnaround. Journal of Forestry 99: 20–25. https://doi.org/10.1093/jof/99.1.20
- Zhang, S., G. Chauret, Q. Tong, 2009: Impact of precommercial thinning on tree growth, lumber recovery and lumber quality in *Abies balsamea*. Scandinavian Journal of Forest Research 24 (5): 425–433. https://doi.org/10.1080/02827580903124392
- Zhang, S.Y., G. Chauret, D.E. Swift, I. Duchesne, 2006: Effects of precommercial thinning on tree growth and lumber quality in a jack pine stand in New Brunswick, Canada. Canadian Journal of Forest Research 36 (4): 945–952. https://doi.org/10.1139/x05-307

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https://doi.org/10.31298/sl.149.11-12.5

Short Communication
Šumarski list, 11-12 (2025): 559-562

A NEW TRITROPHIC ASSOCIATION: *Syspastospora parasitica* ON *Beauveria pseudobassiana* INFECTING *Corythucha arcuata*

Marta KOVAČ[1]

SUMMARY

While studying a sap-feeding insect oak lace bug (*Corythucha arcuata* Say 1832, Heteroptera: Tingidae) and its association with entomopathogenic fungi, a new tritrophic association was discovered: *C. arcuata* infected with entomopathogen *Beauveria pseudobassiana* Rehner & Humber, which in turn is hyperparasitised by mycoparasitic fungus *Syspastospora parasitica* (Tulasne) Cannon & Hawksworth. This hyperparasitic fungus has been reported on various entomopathogenic fungi including *B. pseudobassiana*, but never in tritrophic association with *C. arcuata*. Although fungal hyperparasitism is widespread in nature, it is still poorly studied. In a context of biological control, the interest for hyperparasitic fungi is growing, since entomopathogens have an important role in the regulation of many insect pest populations.

KEY WORDS: biological control, Croatia, entomopathogens, hyperparasitism, mycoparasite, natural infection, oak lace bug

INTRODUCTION

Beauveria pseudobassiana Rehner & Humber (Hypocreales: Cordycipitaceae) is a natural antagonist of oak lace bug (*Corythucha arcuata* Say 1832, Heteroptera: Tingidae), a sap-feeding insect native to North America that is causing foliar damage of oak trees (*Quercus* spp.), first observed in Croatia in 2013 (Hrašovec et al. 2013). Previous studies have shown that this entomopathogenic fungus is consistently present in *C. arcuata* populations and that it is the most common entomopathogen on this species (Kovač et al. 2020, 2021; Kovač 2021). While studying *C. arcuata* and its natural infections with entomopathogenic fungi on different locations in Croatia, we subsequently observed dark brown ascomata emerging from the insects infected with *B. pseudobassiana*. We inferred hyperparasitism, a phenomenon in which one fungus (the mycoparasite) parasitizes another fungus (the host that is also a parasite). A hyperparasitic interaction consists of at least three trophic levels: a primary host, which is parasitized by the primary parasite, which serves as secondary host to the secondary parasite or hyperparasite (Bermúdez-Cova 2023). The aim of this study was to report new tritrophic association with the hyperparasitic fungus on *C. arcuata* infested with *B. pseudobassiana* in natural populations in Croatia.

MATERIALS AND METHODS

During the previous research of *C. arcuata*, carried out in 2019, 2021 and 2022 in different localities in Croatia, many overwintering adults infected with entomopathogen *B. pseudobassiana* were sampled (Kovač 2021, Kovač et al. 2021). Methodology used for sampling and processing of the specimens is described in Kovač et al. (2021). Most of the collected samples were kept in a refrigerator at 4°C and used for the present research. Information on the locations and time of collection can be found in Table 1. Altogether 271 individuals infected with *B. pseudobassiana* were gathered and inspected for the presence of hyperparasitic fungus *S. parasitica*. Adults were first checked under a dissecting microscope (Olympus, model SZX7, Tokyo, Japan) at magnification 40X to visually discern the fungal structures, and the fruiting bodies (perithecia) with emerged spores were

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cut with a sterile needle and microscopically analysed with a phase-contrast microscope (Olympus, model BX53, Tokyo, Japan). The fungus was identified based on the morphology of the fruiting bodies, as well as the size and shape of the ascospores, same as described in Georgieva et al. (2020). The perithecium had globose bases, yellow-brown in colour, with necks of 80–95 µm × 40-42 µm in size. Ascospores were cylindrical, one-celled, 7.5-8 µm long, and 2.5–3 µm wide. The fungus was also isolated on the Potato Dextrose Agar (PDA) medium by taking the whole perithecia with a sterile needle and gently tapping the apices of perithecium necks with spores on a medium. The cultures were incubated for 2–3 weeks at ± 25°C, and purified when needed. After the development of mycelium they were microscopically examined.

RESULTS

After examination of 271 *C. arcuata* individuals infected with entomopathogenic *B. pseudobassiana* 34 of them exhibited mycoparasitic growth on *B. pseudobassiana* (Figure 1a–f). The mycoparasite was identified as *Syspastospora parasitica* (Tulasne) Cannon & Hawksworth (Ascomycota: Hypocreales). The incidence of hyperparasitism varied depending on the locality and collection period (Table 1).

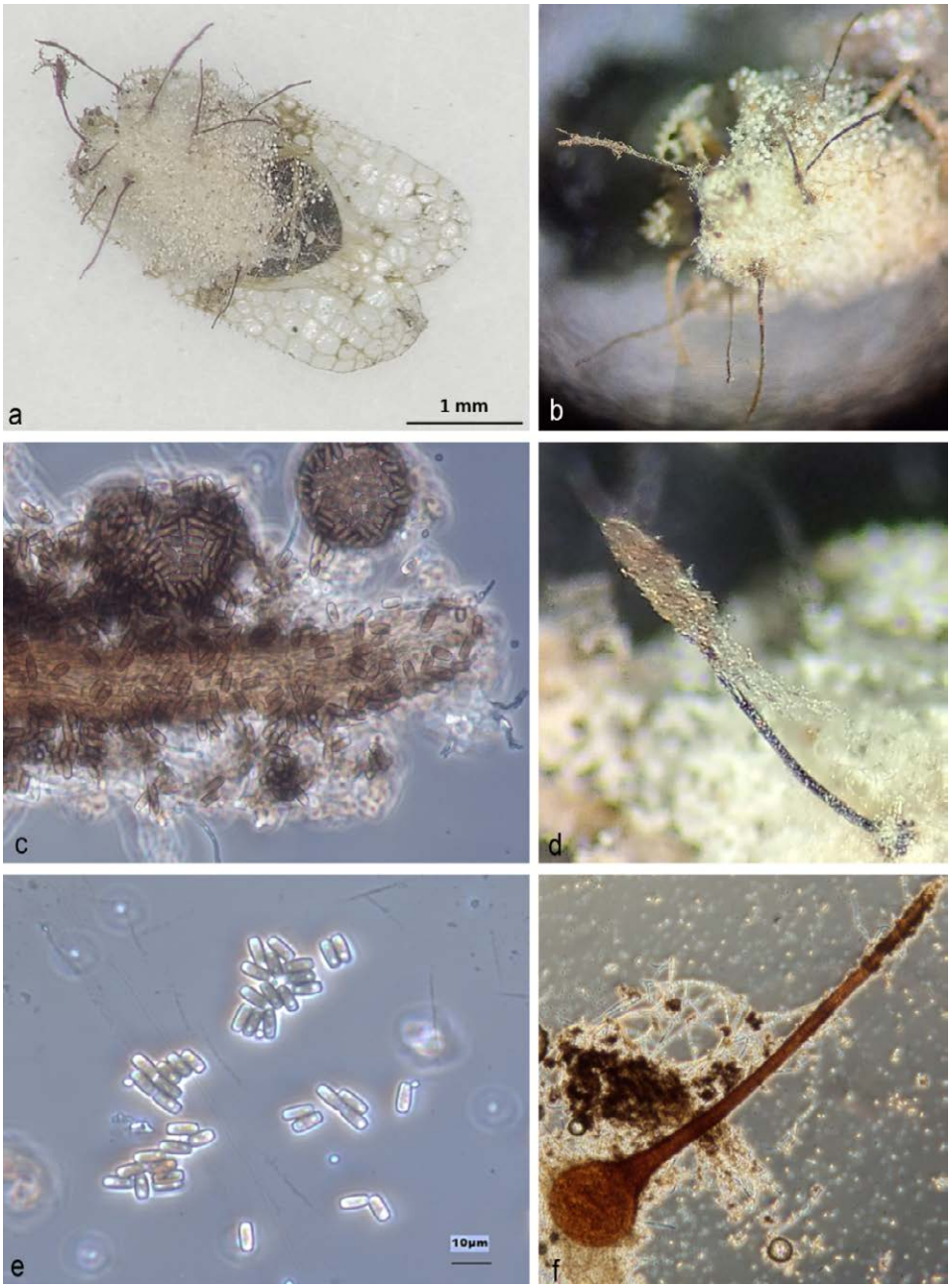

Figure 1 (a) *Corythucha arcuata* adult infested with *B. pseudobassiana* and hyperparasitised by *S. parasitica*; (b) mature *S. parasitica* perithecia growing on *B. pseudobassiana*; (c) ascospores moving to the tip of the perithecium; (d) *S. parasitica* perithecium up close; (e) mature ascospores; (f) dissected perithecium with released ascospores.

Table 1 *C. arcuata* infected by *Beauveria pseudobassiana* and hyperparasitised by *Syspastospora parasitica*, and information on sampling periods and sites.

Collection site		Coordinates	Period of collection	The number of *C. arcuata* infected by *B. pseudobassiana* (n)	The number of *C. arcuata* infected by *B. pseudobassiana* and hyperparasitised by *S. parasitica* (n)	The share of the *C. arcuata* infected by *B. pseudobassiana* and hyperparasitised by *S. parasitica* (%)
Spačva	FO Otok MU Otočke šume	45°08'45.7"N 18°48'16.6"E	March 2019, 2021, 2022	99	26	19%
	FO Gunja MU Desićevo	44°59'41.1"N 18°48'33.6"E	March 2019, 2021, 2022	25	1	
	FO Vrbanja MU Vrbanjske šume	45°02'22.5"N 18°53'16.4"E	March 2019, 2021, 2022	15	1	
	FO Cerna MU Ceranski lugovi	45°10'41.3"N 18°43'54.9"E	December 2019	9	0	
Jaskanski lugovi	MU Jastrebarski lugovi, dep 25b	45°38'11.8"N 15°41'23.4"E	March 2021, 2022	10	0	5%
	MU Jastrebarski lugovi, dep 12a	45°37'25.0"N 15°41'45.5"E	March 2021, 2022	101	6	
	MU Jastrebarski lugovi, Crna Mlaka	45°36'35.0"N 15°42'38.3"E	March 2021, 2022	12	0	
				271	34	12.5%

*MU = Management unit, FO = Forest office, dep = department

DISCUSSION AND CONCLUSIONS

In this research a new tritrophic association is reported for the first time: a mycoparasitic fungus *Syspastospora parasitica* (syn. *Melanospora parasitica* (Tul.)) attacking *B. pseudobassiana* that had infected adult *C. arcuata*. This hyperparasitic fungus has been reported on various entomopathogenic fungi including *B. pseudobassiana* (Georgieva et al. 2020), but never in tritrophic association with *C. arcuata*. According to previous studies, *B. pseudobassiana* was established as a dominating species affecting *C. arcuata* in natural populations of Croatia (Kovač 2021, Kovač et al. 2021), so this new association is an interesting addition to that finding.

The fungus was first described as *Sphaeronema parasitica* Tul. on *Isaria crassa* by Tulasne (1857). So far, *Syspastospora parasitica* was recorded as a secondary parasite of the entomopathogenic fungi *B. pseudobassiana* and *B. varroae* on pine processionary moth *Thaumetopoea pityocampa* (Denis and Schiffermüller 1775) (Lepidoptera: Notodontidae) larvae and pupae (Georgieva et al. 2020), as well as on other *Beauveria* species such as *B. tenella* on *Melolontha* spp. (Coleoptera: Scarabaeidae) (Müller-Kögler 1961), and *B. bassiana* on ash weevil *Stereonychus fraxini* (Coleoptera: Curculionidae) (Markova 1991), Colorado potato beetle *Leptinotarsa decemlineata* (Say) (Posada et al. 2004) *Cydia pomonella* (L.) (Lepidoptera: Tortricidae), and on pupae of pine sawfly *Neodiprion sertifer* (Geoffroy) (Hymenoptera: Diprionidae) (Rosnev and Tsankov 1978). It has also been reported on other entomopathogenic fungi infecting insects such as *Paecilomyces tenuipes* (Peck) Samson attacking *Bombyx mori* L. (Lee and Nam 2000), *Spicaria farinosa* (= *Paecilomyces farinosus*) (Fr.) Vuill. infecting *Boarmia bistortata* Goeze (Lepidoptera: Geometridae), and *Spicaria fumosorosea* (= *P. fumosoroseus*) (Wize) Vassiljevsky infecting *T. pityocampa* (Müller-Kögler 1961).

Although fungal hyperparasitism is widespread in nature, it is still poorly studied, and not ecologically and evolutionarily well understood (Parratt and Laine 2016, Haelewaters et al. 2018, Bermúdez-Cova 2023). However, since entomopathogenic fungi are becoming an increasingly important factor in reducing the population of many insect pests, or at least in keeping their abundance at an acceptable level, in the context of biological control the interest in hyperparasitic fungi is growing.

ACKNOWLEDGMENT

I would like to thank prof. Cezary Tkaczuk from the Institute of Agriculture and Horticulture, University of Natural Sciences and Humanities (Siedlce, Poland) for giving me valuable advice and suggestions regarding the determination of mycoparasite *S. parasitica*.

REFERENCES

- Bermúdez-Cova, M.A., D. Haelewaters, C. de Bekker, M. Piepenbring, N. Schoutteten, A.A. Quandt, 2023: Hyperparasitic fungi—definitions, diversity, ecology, and research. Authorea Preprints. https://doi.org/10.22541/au.168787020.07281183/v2
- Georgieva, M., P. Mirchev, G. Georgiev, 2020: *Syspastospora parasitica* (Tul.) Cannon & Hawksw. (Ascomycota: Hypocreales), a parasite of entomopathogenic fungi (*Beauveria* spp.) attacking pine processionary moth in Bulgaria: new tritrophic associations. Acta Zoologica Bulgarica, Supplementum 15: 97–102.
- Haelewaters, D., T. Hiller, C.W. Dick, 2018: Bats, bat flies, and fungi: A case of hyperparasitism. Trends in Parasitology 34 (9): 784–799. https://doi.org/10.1016/j.pt.2018.06.006
- Hrašovec, B., D. Posarić, I. Lukić, M. Pernek, 2013: Prvi nalaz hrastove mrežaste stjenice (*Corythucha arcuata*) u Hrvatskoj. Šumarski list 137 (9–10): 499–503.
- Kovač, M., M. Gorczak, M. Wrzosek, C. Tkaczuk, M. Pernek, 2020: Identification of entomopathogenic fungi as naturally occurring enemies of the invasive oak lace bug, Corythucha arcuata (Say) (Hemiptera: Tingidae). Insects 11 (10): 679. https://doi.org/10.3390/insects11100679
- Kovač, M., A. Linde, N. Lacković, F. Bollmann, M. Pernek, 2021: Natural infestation of entomopathogenic fungus *Beauveria pseudobassiana* on overwintering *Corythucha arcuata* (Say) (Hemiptera: Tingidae) and its efficacy under laboratory conditions. Forest Ecology and Management 491: 119193. https://doi.org/10.1016/j.foreco.2021.119193
- Kovač, M., 2021: Natural inoculum of entomopathogenic fungi in the overwintering population of oak lace bug *Corythucha arcuata* (Heteroptera, Tingidae). Entomologia Croatica 20 (1): 13–20. https://doi.org/10.17971/ec.20.1.3
- Lee S., S-H. Nam, 2000: A mycoparasitic Ascomycete *Syspastospora parasitica* on the entomopathogenic fungus *Paecilomyces tenuipes* growing in *Bombyx mori*. Mycobiology 28 (3): 130–132. https://doi.org/10.1080/12298093.2000.12015738
- Markova, G., 1991: *Melanospora parasitica* attacking *Beauveria bassiana* on ash weevil *Stereonychus fraxini* in Bulgaria. Journal of Invertebrate Pathology 58: 450–452. https://doi.org/10.1016/0022-2011(91)90193-T
- Müller-Kögler, E., 1961: *Melanospora parasitica* Tul. als Parasit der insektenpathogenen *Beauveria tenella* (Delacr.) Siem. Zeitschrift für Pflanzenkrankheiten und Pflanzenschutz 68: 600–605.
- Parratt, S.R., A.L. Laine, 2016: The role of hyperparasitism in microbial pathogen ecology and evolution. The ISME Journal 10 (8): 1815–1822. https://doi.org/10.1038/ismej.2015.247
- Posada F., F.E. Vega, S.A. Rehner, M. Blackwell, D. Weber, S-O. Suh, R.A. Humber, 2004: *Syspastospora parasitica*, a mycoparasite of the fungus *Beauveria bassiana* attacking the Colorado potato beetle *Leptinotarsa decemlineata*: A tritrophic association. Journal of Insect Science 4: 24. https://doi.org/10.1093/jis/4.1.24
- Rosnev B., G. Tsankov, 1978: *Melanospora parasitica* (Tul.), a secondary parasite of the entomopathogenic fungus *Beauveria bassiana* in Bulgaria. Gorskostopanska Nauka 15 (2): 49–53.
- Tulasne, L., 1857: Note sur les *lsaria* et *Sphaeria* entomogenes. Annales des Sciences Naturelles Botanique 4 (8): 40.

https://doi.org/10.31298/sl.149.11-12.6

Pregledni rad – Review paper
Šumarski list, 11-12 (2025): 563-572

KRPELJI KAO VEKTORI ZOONOTSKIH PATOGENA: JAVNOZDRAVSTVENI ASPEKTI U ISTARSKOJ ŽUPANIJI

TICKS AS VECTORS OF ZOONOTIC PATHOGENS: PUBLIC HEALTH ASPECTS IN THE ISTRIA COUNTY

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SAŽETAK

Praćenje prisutnosti vektora zaraznih bolesti od ključne je važnosti za očuvanje javnog zdravlja te dodatno naglašava potrebu za interdisciplinarnim pristupom u okviru koncepta „Jedno zdravlje" (engl. *One Health*). Ovaj rad temelji se na terenskom istraživanju krpelja kao vektora zoonotskih patogena te analizi pojavnosti krpeljima prenosivih bolesti na području Istarske županije. Podaci Hrvatskog zavoda za javno zdravstvo za razdoblje od 2016. do 2023. godine ukazuju na ukupno 126 prijavljenih slučajeva zoonotskih bolesti, od čega 114 (93,4 %) slučaja lajmske borelioze, dva slučaja Q-groznice te po jedan slučaj rikecioze i hemoragijske vrućice s bubrežnim sindromom. Osam prijavljenih slučajeva zoonoza bilo je evidentirano kod nerezidenata Istarske županije. U okviru istraživanja provedeno je sustavno uzorkovanje tvrdih krpelja (Acari; Ixodidae) u razdoblju od 2020. do 2023. godine metodom krpeljne zatege i prikupljanjem s domaćina, pri čemu je prikupljeno ukupno 2349 jedinki koje pripadaju 12 različitih vrsta iz rodova *Ixodes*, *Dermacentor*, *Hyalomma*, *Haemaphisalis* i *Rhipicephalus* te jedan meki krpelj iz roda *Argas*. Dominantna vrsta bila je obični ili šumski krpelj (*Ixodes ricinus* L.) (70,84 %), poznat vektor bakterija *Borrelia burgdorferi* sensu lato (uzročnik lajmske borelioze) i *Coxiella burnetii* (uzročnik Q-groznice). Rezultati ukazuju na izraženu prisutnost i raširenost vektora odgovornog za prijenos lajmske borelioze, koja je potvrđena kao najzastupljenija zoonoza u regiji. Dobiveni podaci potvrđuju potrebu za kontinuiranim entomološkim nadzorom i epidemiološkim praćenjem vektorski prenosivih bolesti u svrhu bolje procjene rizika i donošenja javnozdravstvenih mjera.

KLJUČNE RIJEČI: Istarska županija, javno zdravlje, krpelji, lajmska borelioza, zoonoze

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UVOD
INTRODUCTION

Praćenje prisutnosti izvora zaraznih bolesti ključno je za očuvanje javnog zdravlja te naglašava potrebu za suradnjom i komunikacijom između različitih disciplina unutar koncepta poznatog kao „Jedno zdravlje" (engl. *One Health*) (Zdolec 2011). Do sada, dokumentiran je porast broja humanih slučajeva zoonoznih oboljenja povezanih sa sitnim glodavcima (Rodentia) (Gebreyes i dr. 2014), a provedene su brojne studije kako bi se bolje procijenila veza između biologije i ekologije životinjskih rezervoara i manifestacija bolesti u ljudi (Meerburg i dr. 2009; Vilibić-Čavlek i dr. 2021, 2023).

Tvrdi krpelji (Acari; Ixodidae) su obligatni hematofagni ektoparaziti i jedna od najvažnijih skupina člankonožaca (Arthropoda) koja sudjeluje u prijenosu različitih patogenih mikroorganizama diljem svijeta (Estrada-Peña i dr. 2013). Njihova sposobnost da se hrane na različitim domaćinima tijekom svojih pokretnih razvojnih stadija omogućuje širenje uzročnika unutar kompleksnih prirodnih žarišta bolesti (Mysterud i dr. 2021). Sitni glodavci (Mammalia; Rodentia) važna su karika u prijenosu lajmske borelioze (Margaletić 2006; Vilibić-Čavlek i dr. 2021, 2023) jer predstavljaju nositelje prvog krvnog obroka za mnoge ličinke i nimfe krpelja, pri čemu se bakterijski uzročnik lajmske borelioze prenosi ugrizom inficiranog krpelja na sljedećeg domaćina, među kojima je i čovjek (Belli i dr. 2017).

Lajmska borelioza i Q-groznica smatraju se reemergentnim zoonozama koje podliježu obvezi prijavljivanja te se epidemiološki prate i u Republici Hrvatskoj (NN 79/07) kao i u zakonima na razini Europske unije (HZJZ 2017).

Simptomi lajmske borelioze su umor, zimica, vrućica, glavobolja, bolovi u mišićima i zglobovima te povećani limfni čvorovi uz karakterističan osip na koži (*erythema migrans*) (Stanek 2012). U razdoblju od 2. do 30. dana na mjestu ugriza krpelja pojavljuje se crvenilo na koži ovalnog ili prstenastog oblika koje se polako širi, doseže promjer obično više od 5 cm, a u središnjem dijelu postupno blijedi stvarajući karakterističan oblik (Skar 2024). Lajmska borelioza liječi se antibioticima, što je izuzetno važno radi sprječavanja kasnijeg stadija bolesti s mogućim posljedicama kao što su artritis (upala zglobova), miokarditis (upala srčanog mišića), meningitis i/ili neuritis (upala živaca) (HZJZ 2016). Prema podacima Hrvatskog zavoda za javno zdravstvo (HZJZ), u razdoblju od 2001. do 2023. godine u Republici Hrvatskoj prosječni godišnji broj prijavljenih slučajeva lajmske borelioze iznosio je 396, pri čemu nije zabilježen nijedan smrtni ishod (napomena: podaci za 2024. godinu još nisu dostupni u službenim izvorima HZJZ-a.). Prema zemljopisnoj rasprostranjenosti najveći broj oboljelih od lajmske bolesti zabilježen je u Zagorju, Međimurju, Koprivničko-križevačkoj županiji, a zatim u gradu Zagrebu i okolici Zagreba (HZJZ 2016), dok se Istra smatra područjem s manjom incidencijom ove bolesti (Ropac 2019).

Najrasprostranjenija vrsta krpelja na području Istarske županije je obični ili šumski krpelj (*Ixodes ricinus* L.) (70,84 %) (Cvek i dr. 2023), poznat kao najčešći vektor lajmske borelioze te Q-groznice. Ova vrsta krpelja parazitira na najmanje 25 različitih vrsta domaćina (Krčmar 2012) i prijenosnik je više vrsta patogenih mikroorganizama (Hayasaka i dr. 2001, Rauter i dr. 2005, Stuen 2007, Sameroff i dr. 2022). Njegov životni ciklus u prosjeku traje dvije do četiri godine te uključuje četiri razvojna stadija: jaje, ličinku, nimfu i adulta (Richter 2002). Odrasli oblici običnog krpelja najčešće infestiraju srednje i velike sisavce, dok se larve i nimfe u većoj mjeri nalaze na manjim domaćinima, premda su nimfe također prisutne i na većim sisavcima, uključujući čovjeka (Mysterud i dr. 2021).

Uzročnik Q-groznice je vrlo infektivna unutarstanična bakterija *Coxiella burnetii* koja je raširena po cijelom svijetu. Izvan živog organizma vrsta *C. burnetii* tvori spore koje su izuzetno otporne na vanjske uvjete, a u kontaminiranom tlu mogu opstati i po nekoliko mjeseci. Kako se spore ove bakterije prenose i zrakom te je za infekciju ljudi potrebno manje od 10 spora, ova vrsta se smatra potencijalnim biološkim oružjem (Rowe 2015). U ljudi, Q-groznica može proći neopaženo, ali može biti i akutnog ili kroničnog tijeka. Akutna infekcija očituje se glavoboljom, febrilitetom, bolovima u kostima i upalom pluća, a kronična infekcija rezultira hepatitisom, endokarditisom i neurološkim sindromima. U slučaju neadekvatnog liječenja bolest može dovesti do smrtnog ishoda. Životinje zaražene ovom bakterijom najčešće ne pokazuju simptome infekcije, no izvori su infekcije za ljude i druge životinje (Račić 2012). Neki glodavci, posebno poljska voluharica (*Microtus arvalis* Pallas), osjetljivi su na infekcije bakterijom *C. burnetii* (Reháček 1977, 1992). Na području Istarske županije ranije je utvrđena prisutnost vrsta krpelja koje pripadaju pet rodova (*Ixodes*, *Dermacentor*, *Rhipicephalus*, *Haemaphysalis* i *Hyalomma*) (Krčmar 2012), od kojih se pojedine vrste navode kao potencijalni vektori uzročnika Q-groznice u Europi (Körner i dr. 2021). Pretpostavlja se da upravo krpelji prenose patogenu bakteriju *C. burnetii* između malih glodavaca i drugih sisavaca u tzv. prirodnim žarištima i predstavljaju bitnu kariku za održavanje Q-groznice u endemskim područjima (Liebisch 1977, Mulić 2011, Duron i dr. 2015).

Sustavno prikupljanje i analiza podataka o prisutnosti i rasprostranjenosti krpelja, kao i o pojavnosti povezanih zoonotskih bolesti, nužni su za razumijevanje javnozdravstvenih rizika koje ti vektori predstavljaju te za usmjeravanje učinkovitih mjera prevencije i kontrole (Rizzoli 2014). Cilj ovog istraživanja bio je ispitati rasprostranjenost i zastupljenost krpelja kao vektora zoonotskih patogena na području Istarske županije te analizirati dostupne podatke o pojavnosti zoonoza povezanih s tim vektorima u svrhu razumijevanja javnozdravstvenih aspekata rizika.

MATERIJAL I METODE

MATERIAL AND METHODS

Područje istraživanja – *Study area*

Istra je najveći jadranski poluotok, smješten na najzapadnijem dijelu Hrvatske. Istarska županija ima ukupnu površinu od 2813 km^2, sa 195.237 stanovnika koji žive u 10 gradova i 31 općini (DZS 2022). Uz obalu Istre prevladava sredozemna klima koja se postupno mijenja prema unutrašnjosti i postaje kontinentalna. Glavna obilježja sredozemne klime su topla i suha ljeta, s prosječnim brojem od 2.400 sunčanih sati godišnje. Zime su blage i ugodne, a snijeg je rijetka pojava. Godišnji prosjek temperatura zraka duž sjevernog dijela obale iznosi oko 14 °C, a na južnom području i otocima 16 °C (Moj Tender 2020). Od šumskih zajednica na području istarskog poluotka, u obalnim područjima zastupljene su submediteranske i epimediteranske termofilne, listopadne šume hrasta medunca s bjelograbićem ili crnim grabom, dok u unutrašnjosti nalazimo termofilne, kalcifilne do slabo acidofilne šume hrasta kitnjaka i medunca te paramediteranske brdske, primorske i kontinentalne termofilne šume bukve (Vukelić i Rauš 1998). Specifičan položaj Istre uz navedene klimatske uvjete i vegetacijski pokrov, pruža pogodno stanište za krpelje.

Uzorkovanje krpelja i prikupljanje podataka o slučajevima zaraze zoonozama – *Tick sampling and collecting data on cases of zoonotic infections*

Sukladno zakonskoj regulativi (NN 133/23), u Nastavnom zavodu za javno zdravstvo Istarske županije (NZZJZIŽ) prikupljaju se podaci o pojavi humanih slučajeva zoonoza te se dostavljaju Hrvatskom zavodu za javno zdravstvo. Prijave zaraznih bolesti provode se putem informacijskog sustava APIS IT od 2016. godine. U ovom radu prikazani su analizirani podaci o zoonozama u čijoj transmisiji uzročnika sudjeluju tvrdi krpelji na području Istarske županije za period od 2016. do 2023. godine. Pregledom godišnjih izvješća o pojavi bolesti u životinja u Republici Hrvatskoj (NN 42/13) prikupljeni su podaci o zoonozama u kojima krpelji imaju važnu ulogu.

Uzorci krpelja prikupljani su u razdoblju od 2020. do 2023. godine na području Istarske županije. Provedene tehnike uzorkovanja uključivale su kombiniranu metodu krpeljne zatege i prikupljanje s domaćina. Metodom krpeljne zatege uzorkovani su krpelji na različitim tipovima staništa, uključujući gradske parkove, rekreacijska područja, izletišta, neobrađene poljoprivredne površine, Nacionalni park Brijuni te šumske površine. Uzorkovanje krpeljnom zategom uključivalo je povlačenje platna od bijelog flanela, dimenzije 1 m × 1 m (pričvršćenog na drvenu letvicu, rubova spojenih užetom) po površini tla, preko niskog raslinja i preko listinca u dužini od oko 200 metara. Platno se pregledavalo s jedne i druge strane, svakih 10-ak metara, kako bi se utvrdila prisutnost ulovljenih krpelja. Za uklanjanje tvrdih krpelja s platna korištena je pinceta. Osobna zaštitna oprema korištena tijekom rada uključivala je repelent protiv krpelja, jednokratne (lateks) rukavice i dezinficijens. Pronađene jedinke tvrdih krpelja pohranjene su u epruvete (2 mL) i transportirane u NZZJZIŽ gdje je obavljena determinacija uzorkovanih krpelja, utvrđivanje razvojnog stadija, odnosno spola jedinki. Također, krpelji su prikupljani i s različitih domaćina (domaćih i divljih životinja te kućnih ljubimaca) na području Istarske županije.

Provedena je morfološka determinacija krpelja uz pomoć ključeva za određivanje vrsta krpelja (Estrada-Peña i dr. 2014) te uz pomoć stereo mikroskopa Olympus SZX9 (OLYMPUS OPTICAL CO. EUROPA GMBH, Hamburg, Njemačka), a svi primjerci fotografirani su digitalnim fotoaparatom (Olympus SC50, Münster, Njemačka). Svi sakupljeni krpelji pohranjeni su na –80 °C za potrebe daljnjih analiza.

Statistička obrada – *Statistical analysis*

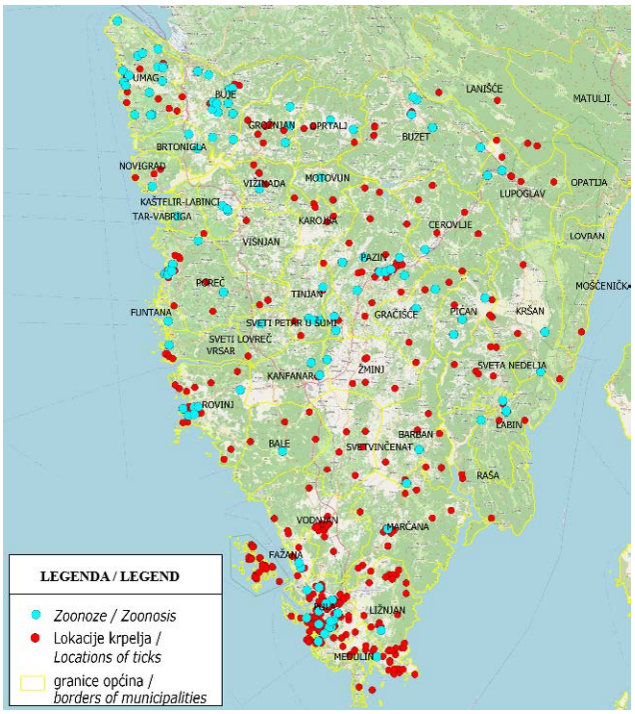
Pomoću računalne GIS aplikacije QGIS (QGIS v3, Gossao, Švicarska) izvršena je usporedba i vizualizacija prostorne raspodjele prijavljenih zoonoza i prikupljenih krpelja na području Istarske županije. Statistička analiza zoonoza izvršena je pomoću programske podrške Statistica® v. 14.0 na razini značajnosti $p < 0,05$. Raspodjela zoonoza u ovisnosti o spolu, dobnoj skupini oboljelih, lokaciji, godini oboljenja i klasifikaciji slučajeva (vjerojatan i potvrđen) provedena je analizom glavnih komponenti (PCA).

REZULTATI I RASPRAVA

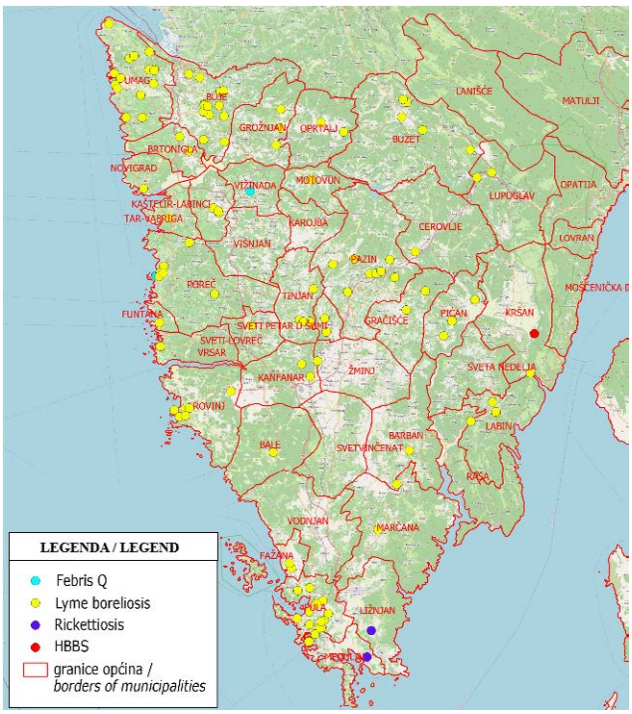
RESULTS AND DISCUSION

Radi učinkovitije zaštite zdravlja ljudi i životinja od krpeljima prenosivih zoonoza te očuvanja okolišne sigurnosti, ovaj rad usmjeren je na analizu prisutnosti i distribucije krpelja kao vektora patogena na području Istarske županije. Korištenjem podataka o prijavljenim

zoonozama koje se prenose krpeljima te prostornom analizom učestalosti i raspodjele vektora može se stvoriti uvid u potencijalne javnozdravstvene rizike povezane s njihovom pojavom. Na Slici 1 prikazana je prostorna distribucija zoonotskih bolesti prijavljenih na području Istarske županije u razdoblju od 2016. do 2023. godine koja predstavlja temelj za daljnju interpretaciju i usporedbu sa zastupljenošću prikupljenih i identificiranih krpelja na istom području u razdoblju od 2020. do 2023., što je prikazano na Slici 2.



Slika 1. Prostorna raspodjela zoonoza u razdoblju 2016. – 2023. te lokacije prikupljenih i identificiranih krpelja u Istri u razdoblju 2020. – 2023.
Figure 1 Spatial distribution of zoonosis in the period 2016 – 2023 and locations of collected and identified ticks in Istria in the period 2020 – 2023.



Slika 2. Prostorna analiza svih zoonoza prijavljenih u Istri u razdoblju 2016. – 2023.
Figure 2 Spatial analysis of all zoonosis reported in Istria in the period 2016 – 2023.

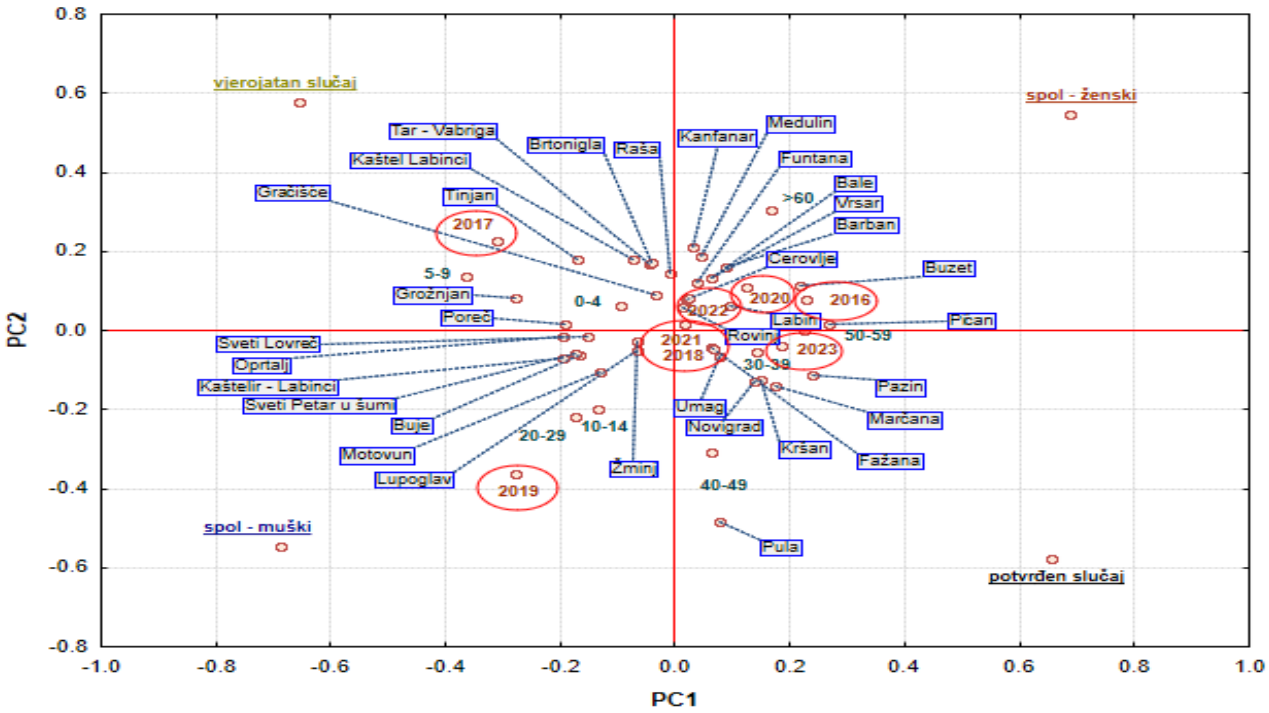
Tijekom istraživanog razdoblja (2016. – 2023.) na području Istarske županije ukupno je prijavljeno 126 slučajeva zaraznih bolesti koje se prenose putem člankonožaca, odnosno zoonoza čiji su vektori krpelji. Od toga, 122 slučaja (96,8 %) odnosila su se na lajmsku boreliozu, dok su preostala četiri slučaja obuhvaćala druge zoonoze: dva slučaja Q-groznice (1,6 %) (Poreč, 2016. i naselje Danci, općina Vižinada, 2018.), jedan slučaj (0,8 %) hemoragijske groznice s bubrežnim sindromom (Houck i dr. 2001, Valiente i dr. 2005, Kršan 2019) te jedan slučaj (0,8 %) rikecioze (Šišan, općina Ližnjan, 2016.). Od ukupno 122 slučaja lajmske borelioze, 114 (93,4 %) je evidentirano kod rezidenata Istarske županije, dok se osam slučajeva (6,6 %) odnosilo na osobe koje nisu stanovnici županije te stoga nisu uključeni u analizu. Sukladno tome, u ovom radu detaljno je obrađeno i analizirano 114 slučajeva lajmske borelioze u lokalnom stanovništvu, kao i ostale četiri potvrđene zoonoze zabilježene na području županije tijekom navedenog razdoblja.

Analiza slučajeva lajmske borelioze prijavljenih na području Istarske županije u razdoblju od 2016. do sredine 2023. godine pokazuje da su najviši godišnji brojevi zabilježeni 2018. godine (23 prijavljena slučaja) i 2019. godine (19 slučajeva). Najmanji broj oboljelih zabilježen je 2021. godine, s ukupno četiri prijavljena slučaja. U preostalim godinama analiziranog razdoblja (2016., 2017., 2020. i 2022.), broj prijava varirao je između 12 i 16 slučajeva godišnje, što ukazuje na određene godišnje oscilacije u pojavnosti bolesti.

Nadalje, analiziran je i udio oboljelih od borelioze po dobnim skupinama gdje je najveći broj od 25 oboljelih zabilježen u dobnoj skupini osoba starijih od 60 godina, što čini 22 % ukupnog broja oboljelih, zatim u dobnim skupinama između 30 i 39 godina te između 50 i 59 godina s 20 (18 %) odnosno 19 (17 %) slučajeva oboljenja. Kod mlađe populacije najveći broj slučajeva bolesti prijavljen je u dobnoj skupini između 5 i 9 godina – 18 slučajeva (16 %) i kod dobne skupine mlađe djece do 4 godine starosti – 9 slučajeva (8 %).

Analiza incidencija lajmske borelioze, raspoređenih po jedinicama lokalne samouprave na području Istarske županije u razdoblju od 2016. do 2023., ukazuje na to da je najveći broj humanih slučajeva lajmske borelioze

evidentiran u urbanim sredinama, dok je znatno manji broj slučajeva zabilježen u ruralnim sredinama. Sukladno tome, najveći broj prijavljenih slučajeva bolesti bilježe područja gradova Umaga (16), Buja (14), Pule (12), Poreča i Pazina (8). Jedinice lokalne samouprave u kojima je tijekom promatranog razdoblja zabilježen samo jedan slučaj bolesti objedinjene su pod kategoriju „ostali", a takvih je prijava bilo ukupno 12. U pogledu pojave bolesti u životinja za tri praćene zoonoze koje se prenose sa životinje na čovjeka (lajmska borelioza, Q-groznica i rikecioza), zabilježeni su slučajevi isključivo Q-groznice u goveda, i to tijekom 2017., 2020. i 2022. godine. U cilju utvrđivanja incidencije bolesti lajmske borelioze po dobi i spolu, u praćenom razdoblju (2016. – 2023.) korištena je statistička analiza glavnih komponenti (PCA). Raspodjela podataka analiziranih varijabli prikazana je u vektorskoj ravnini (Slika 3). Testiranje primjerenosti uporabe analize glavnih komponenti provedeno je testom prema Kasier-Meyer-Olkinu, pri čemu je indeks podudarnosti iznosio 0,812 te se njegova vrijednost može ocijeniti kao vrlo dobra, što je preduvjet za provedbu PC analize. Za određivanje broja glavnih komponenti koje su zadržane u analizi korišten je Cattellov „scree" test. Prema tom testu, u analizi su zadržane tri glavne komponente (PC1, PC2 i PC3) koje objašnjavaju 84,4 % ukupne varijance. Prva glavna komponenta PC1 objašnjava 45,6 % ukupne varijance, dok druga PC2 i treća PC3 24,5 %, odnosno 14,3 %.



Slika 3. Raspodjela broja oboljelih od lajmske borelioze ovisno o spolu oboljelih (muškarci i žene), godini prijavljenih slučajeva bolesti (2016. – 2023.), klasifikaciji slučajeva bolesti (vjerojatan i potvrđen) i jedinicama lokalne samouprave na području Istarske županije u razdoblju od 2016. do 2023. u faktorskoj ravnini predstavljena analizom glavnih komponenti (PCA) u prve dvije glavne komponente (PC).
Figure 3 Distribution of the number of Lyme borreliosis patients depending on the gender of patients (men and women), the year of reported disease cases (2016–2023), the classification of disease cases (probable and confirmed) and local self-government units in Istria County in the period from 2016 until 2023 in the factor plane represented by principal component analysis (PCA) in the first two principal components (PC).

Analizirajući distribuciju promatranih varijabli na PCA faktorskoj ravnini, vidljivo je da su varijabla dobnih skupina starije dobi (od 30 do > 60 godina) te godine tijekom kojih su prijavljeni slučajevi bolesti (2016., 2018., 2020. – 2023.) raspoređeni u prvom i drugom kvadrantu vektorske ravnine definirajući pozitivnu stranu prve glavne komponente (desna strana PC1). Nadalje, desnu stranu PC1 definira i klasifikacija slučaja: potvrđena bolest (1. kvadrant faktorske ravnine), ženski spol oboljelih (2. kvadrant faktorske ravnine), kao i većina urbanih sredina u kojima je detektiran veći broj slučajeva bolesti (Umag, Pula, Pazin). S lijeve strane glavne komponente PC1 raspoređene su varijable: dobnih skupina mlađe životne dobi (od 0 do 29 godina), godine tijekom kojih su prijavljeni slučajevi bolesti (2017. i 2019.), vjerojatni slučajevi bolesti te muška populacija oboljelih (3. i 4. kvadrant). S iste strane faktorske ravnine nalaze se ruralne sredine u kojima je prijavljen manji broj slučajeva bolesti (osim grada Buja). U svrhu razjašnjenja važnosti pojedinačnih varijabli uključenih u definiciju modela glavnih komponenata, korišteni su pokazatelji: vrijednost svojstvenih vektora i važnost varijabli (Tablica 1). Analizirajući vrijednosti svojstvenih vektora, može se uočiti da najveći broj varijabli definira glavnu komponentu PC1 (osam varijabli). Jak pozitivan učinak na definiciju PC1 imaju sljedeće varijable: potvrđen slučaj

(0,66) i ženski spol (0,69), dok je utjecaj varijabli dob (30 – 39) i lokacija grada Umaga pozitivan, ali vrlo slab (< 0,14). S druge strane, varijable vjerojatan slučaj (–0,66) i muški spol (–0,69) pokazuju jak negativan učinak na PC1. Varijable godina 2019. (–0,36) i lokacija grada Pule (–0,48) definiraju glavnu komponentu PC2, pri čemu je njihov utjecaj na definiranje PC2 umjereno jak i negativan. Glavnu komponentu PC3 definiraju varijable: dob (> 60 godina) s jakim pozitivnim učinkom (0,57) i varijable: dob (50 – 59) i godina 2020. s jakim negativnim učinkom (–0,49 i –0,58).

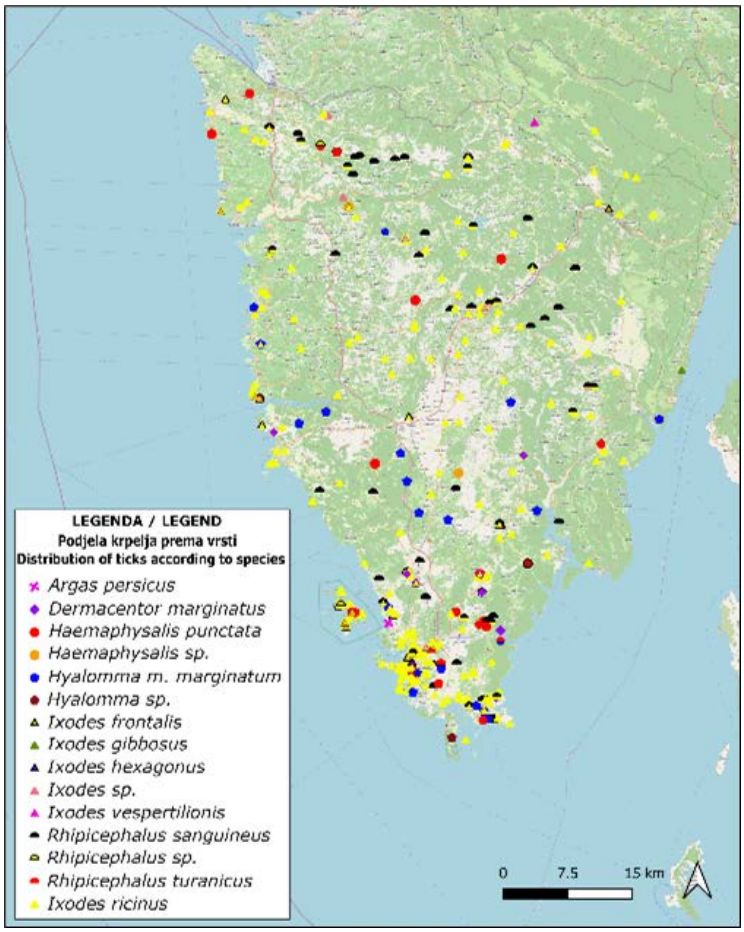
Tablica 1. Vrijednosti svojstvenih vektora i važnost varijabli za klasifikaciju slučajeva (vjerojatan i potvrđen), spola oboljelih (muški i ženski), dobnih skupina oboljelih, godina tijekom kojih su prijavljeni slučajevi lajmske borelioze i prisutnost slučajeva u jedinicama lokalne samouprave predstavljene analizom glavnih komponenti (PCA) u prve četiri glavne komponente. Različitim bojama prikazane su varijable koje definiraju pojedinu glavnu komponentu. Za posljednje tri navedene varijable prikazane su samo one s najjačom snagom i važnosti. Različitim bojama prikazane su varijable koje definiraju pojedinu glavnu komponentu.
Table 1 Values of eigenvectors and the importance of variables for the classification of cases (probable and confirmed), gender of patients (male and female), age groups of patients, years during which Lyme disease cases were reported and the presence of cases in local self-government units presented by principal component analysis (PCA) in the first four main components. The variables that define each main component are shown in different colors. For the last three listed variables, only those with the greatest strength and importance are shown. The variables that define each main component are shown in different colors.

Varijabla *Variable*	Vrijednosti svojstvenih vektora *Values of eigenvectors*			Važnost varijabli *Importance of variables*	
	PC 1	PC 2	PC 3	Snaga *Strength*	Važnost *Importance*
vjerojatan slučaj / *probable case*	–0,66	0,58	–0,04	0,87	2
potvrđen slučaj / *confirmed case*	0,66	–0,58	0,04	0,87	2
spol – muški / *gender – male*	–0,69	–0,55	0,08	0,81	4
spol – ženski / *gender – female*	0,69	0,55	–0,08	0,81	4
dob / *age* (> 60)	0,17	0,30	0,57	0,58	5
dob / *age* (50 – 59)	0,22	0,00	–0,49	0,46	9
dob / *age* (30 – 39)	0,14	–0,05	0,04	0,56	7
godina / *year* 2019	–0,28	–0,36	–0,25	0,58	6
godina / *year* 2020	0,12	0,11	–0,58	0,49	8
godina / *year* 2017	–0,31	0,23	–0,08	0,44	10
grad Pula / *the city of Pula*	0,08	–0,48	–0,04	0,26	13
grad Umag / *the city of Umag*	0,10	–0,07	–0,08	0,24	15
grad Poreč / *the city of Poreč*	–0,19	0,01	–0,17	0,18	17

Analizom važnosti varijabli utvrđeno je da klasifikacija slučajeva bolesti (vjerojatan i potvrđen) pokazuju najjači utjecaj u definiciji modela sa snagom od 0,87 (Tablica 1), dok jak utjecaj na definiranje modela pokazuje varijabla spol (muški i ženski) od 0,81. Srednje jak utjecaj pokazuju varijable dob >60 godina (0,58) i godina (0,58), dok je utjecaj lokacije grada Pule slab (0,26). Tijekom ispitivanog razdoblja prijavljivanja bolesti lajmske borelioze u većini slučajeva kod ženske populacije bio je potvrđen slučaj bolesti. Ženska populacija srednje ili starije životne dobi bila je više izložena pobolu prvenstveno u razdoblju od 2020. do 2023. Isto tako, broj slučajeva bolesti ženske populacije bio je dominantno prisutan u urbanim sredinama. Kod muške populacije bolest u većini slučajeva nije potvrđivana nego je pretpostavljeno da se radilo o oboljenju. Obolijevala je pretežno mlađa muška populacija, pogotovo u dobi od 0 do 14 godina u ruralnim sredinama. Na osnovi svega navedenog može se zaključiti da na pojavnost lajmske borelioze najjači utjecaj imaju varijable: klasifikacija slučaja i spol oboljelih.

Na području Istarske županije ukupno je prikupljeno 2349 jedinki krpelja pripadnika 12 vrsta čiji je prostorni raspored prikazan na Slici 4. Od tog broja metodom krpeljne zatege prikupljeno je ukupno 1247 krpelja (53,1 %), od čega preko 89 % otpada na vrstu obični ili šumski krpelj (*I. ricinus* L. 1758). Identificirane su i vrste *Haemaphysalis punctata* (Canestrini & Fanzago, 1878) sa zastupljenošću od 4 %, *Ixodes frontalis* (Panzer, 1795) i *Rhipicephalus sanguineus* (Latreille, 1806) s 2,5 %, rod *Rhipicephalus sp.* (Koch, 1844) s 1,5 % te *Dermacentor marginatus*, *Haemaphysalis sulcata* (Canestrini & Fanzago, 1878), *Hyalomma marginatum* (Koch, 1844) s < 1 % od ukupnog broja krpelja prikupljenih krpeljnom zategom.

Ukupno je prikupljeno 1102 krpelja (46,9 %) metodom izolacije s domaćina. Dominantna vrsta i ovom je metodom bio *I. ricinus*, no s nižim relativnim udjelom (50 %) u odnosu na metodu prikupljanja krpeljnom zategom. Nasuprot tome, *R. sanguineus* i *H. marginatum* pokazale su znatno veću zastupljenost (24 % i 13 %) u usporedbi s udjelima zabilježenim prilikom primjene metode krpeljne zatege (2,5 % i 0,3 %). Ovom metodom



Slika 4. Prostorna raspodjela različitih vrsta krpelja na području Istre, prikupljenih metodom krpeljne zatege i prikupljanjem s domaćina (životinje/čovjeka).
Figure 4 Spatial distribution of different species of ticks collected by the flagging method and collection from the host (animal/human) in the area of Istria County.

dodatno su detektirane i vrste koje prethodno nisu bile registrirane, uključujući jedinku roda *Hyalomma* (8 %) te vrste *Rhipicephalus turanicus* (Pomerantsev, 1936) (2 %), *Ixodes gibbosus* (Nuttall, 1916), *Ixodes hexagonus* (Leach, 1815) i *Ixodes vespertilionis* (Koch, 1844). Primjenom ove metode uzorkovan je i meki krpelj *Argas persicus* (Oken, 1818), s udjelom manjim od 1 %. Vrsta *D. marginatus* zabilježena je u obje metode uzorkovanja, pri čemu su udjeli bili vrlo slični. Nasuprot tome, vrste iz roda *Haemaphysalis* (*H. punctata* i *Haemaphysalis* sp.) te *I. frontalis* pokazale su nižu zastupljenost u odnosu na metodu krpeljne zatege (2 % i 0,3 %). Dobiveni rezultati upućuju na izraženiju prisutnost vrsta čiji se juvenilni stadiji hrane na glodavcima, a poznati su vektori uzročnika zoonoza kao što su lajmska bolest i Q-groznica (Lee i dr. 1990, Schmaljohn i Hjelle 1997, Brummer-Korvenkontio i dr. 1999, Fischer i dr. 2000, Olsson i dr. 2002).

U Republici Hrvatskoj, kao i u mnogim europskim zemljama, nedostaju prostorni podaci o distribuciji i aktivnosti vektora (ECDC 2018). Prostorna distribucija krpelja u određenoj regiji ključna je za procjenu rizika od bolesti koje krpelji prenose i vrijedna je informacija za razumijevanje ekološke dinamike interakcija krpelja i domaćina te potencijalnog utjecaja na divlje i domaće životinje i cjelokupno zdravlje ekosustava (Léger i dr. 2013).

Psi su se pokazali kao učinkoviti bioindikatori za praćenje prisutnosti krpelja i procjenu rizika od infekcija koje oni prenose, uključujući *Borrelia burgdorferi*, uzročnika lajmske borelioze. Njihova sklonost kretanju kroz staništa bogata vegetacijom, kao i blizak kontakt s ljudima, čini ih vrijednim izvorom informacija o prisutnosti vektora u određenim područjima (Duncan 2004). Tijekom ovog istraživanja, najveći broj krpelja u urbanim sredinama prikupljen je s pasa, što dodatno potvrđuje njihovu ulogu u otkrivanju i praćenju prisutnosti krpelja u okolišu. Za razliku od toga, slučajevi humanih zoonoza – rikecioza i Q-groznice – zabilježeni su isključivo u ruralnim sredinama. Isti trend pojavnosti bolesti u ruralnim sredinama zabilježen je i u domaćih životinja, ali ne na istim lokacijama, iz čega se može zaključiti da slučajevi nisu povezani, odnosno da patogen nije prenesen s domaće životinje na čovjeka.

Rezultati analize podataka ukazuju da su od lajmske borelioze češće obolijevale žene (58 %) u odnosu na muškarce (42 %). Ti podaci u skladu su s podacima iz drugih država, odnosno ne pokazuju značajne razlike u stopama lajmske borelioze između muškaraca i žena u zemljama SAD-a i Europe (Burn i dr. 2023) kao i s podacima

prikupljenim u sjevernim i kontinentalnim dijelovima Republike Hrvatske (Ropac 2019) gdje je prosječno godišnje prijavljeno 494 slučajeva bolesti pretežito među osobama ženskog spola. Razlog tome može biti razlika u eksponiranosti infekciji, spolnim razlikama u kliničkoj manifestnosti infekcije te u redovitijem odlasku na pregled osoba ženskog spola, a time i češće registracije bolesti među njima (Ropac 2019).

ZAKLJUČAK

CONCLUSION

Krpelji, kao jedni od najznačajnijih vektora brojnih zoonotskih patogena, imaju ključnu ulogu u održavanju i prijenosu bolesti koje predstavljaju ozbiljan javnozdravstveni izazov. Provedeno istraživanje na području Istarske županije u razdoblju od 2016. do 2023., uz primjenu GIS metodologije, omogućilo je prostornu analizu prisutnosti krpelja i zoonoza čijoj transmisiji doprinose. Posebna vrijednost ovog istraživanja ogleda se u sveobuhvatnom entomološkom nadzoru tijekom kojeg je, u razdoblju od 2020. do 2023. godine, identificirano 12 vrsta krpelja pripadnika svih pet rodova prisutnih u Hrvatskoj (*Ixodes*, *Dermacentor*, *Haemaphysalis*, *Hyalomma* i *Rhipicephalus*), uključujući i mekog krpelja *Argas persicus* – po prvi put zabilježenog u ovom obuhvatu na razini županije. Najzastupljenija vrsta bila je *I. ricinus*, vektor uzročnika dviju najčešćih zoonoza u regiji – *B. burgdorferi* sensu lato i *C. burnetii*, uzročnika lajmske borelioze i Q-groznice.

Analiza epidemioloških podataka ukazala je na 126 prijavljenih slučajeva bolesti koje prenose krpelji, od čega je čak 96,8 % činila lajmska borelioza. Statistički značajna učestalost bolesti zabilježena je u urbanim sredinama, osobito među ženskom populacijom starije životne dobi. Analizom je utvrđeno da na pojavnost bolesti najuže utječu potvrđena dijagnoza, spol i dob (> 60 godina), što dodatno naglašava potrebu za ciljanom preventivnom strategijom.

Dobiveni rezultati potvrđuju važnost sustavnog nadzora vektora i prepoznavanja područja povećanog rizika za prijenos bolesti na ljude. Praćenje prostorne distribucije krpelja ključno je za razumijevanje ekološke dinamike prijenosa patogena i planiranje učinkovitih javnozdravstvenih mjera. U skladu s pristupom „Jednog zdravlja", provedba integriranog nadzora – uz međusektorsku suradnju javnozdravstvenih, veterinarskih i ekoloških službi – temelj je za učinkovito upravljanje vektorski prenosivim bolestima. Ovi nalazi dodatno naglašavaju potrebu za trajnim, koordiniranim epidemiološkim nadzorom i edukacijom stanovništva o rizicima koje krpelji predstavljaju za zdravlje ljudi i životinja.

LITERATURA

REFERENCES

- Belli, A., A. Sarr, O. Rais, R.O.M. Rego, M.J. Voordouw, 2017: Ticks infected via co-feeding transmission can transmit Lyme borreliosis to vertebrate hosts. Scientific Reports 7 (1): 5006. https://doi.org/10.1038/s41598-017-05231-1
- Brummer-Korvenkontio M., O. Vapalahti, H. Henttonen, P. Koskela, P. Kuusisto, A. Vaheri, 1999: Epidemiological study of Nephropathia epidemica in Finland, 1989-96. Scandinavian Journal of Infectious Diseases 31 (5): 427–435. https://doi.org/10.1080/00365549950163941
- Burn, L., A. Pilz, A. Vyse, A.V. Gutiérrez Rabá, F.J. Angulo, T.M. Phuong Tran, M.A. Fletcher, B.D. Gessner, J.C. Moïsi, J.H. Stark, 2023: Seroprevalence of Lyme borreliosis in Europe: Results from a systematic literature review (2005–2020). Vector-Borne and Zoonotic Diseases 23 (4): 195–220. https://doi.org/10.1089/vbz.2022.0069
- Cvek, M., D. Puškadija, M. Jakac, N. Landeka, E. Pustijanac, D. Tomić Linšak, 2023: Uloga krpelja kao vektora zoonoza s osvrtom na bolesti koje oni prenose na području Istarske županije. U: Zbornik sažetaka, 3. Hrvatski simpozij biologa u zdravstvu. Zagreb, 25. 11. 2023., pp. 12–12.
- DZS, 2022: Prvi digitalni popis stanovništva 2021. Državni zavod za statistiku. https://dzs.gov.hr/en
- Duncan, A.W., 2004: The dog as a sentinel for human infection: Prevalence of Borrelia burgdorferi C6 antibodies in dogs from southeastern and mid-Atlantic states. Vector-Borne and Zoonotic Diseases 4 (3): 221–229. https://doi.org/10.1089/vbz.2004.4.221
- Duron O., K. Sidi-Boumedine, E. Rousset, S. Moutailler, E. Jourdain, 2015: The importance of ticks in Q Fever transmission: what has (and has not) been demonstrated? Trends in Parasitology 31 (11): 536–52. https://doi.org/10.1016/j.pt.2015.06.014
- Estrada-Peña, A., A. Bouattour, J.-L. Camicas, A.R. Walker, 2014: Ticks of domestic animals in the Mediterranean region: A guide to identification of species. University of Edinburgh, Edinburgh, UK.
- Estrada-Peña, A., A.D. Mihalca, T.N. Petney, 2013: Ticks of Europe and North Africa: A guide to species identification. Springer. https://doi.org/10.1007/978-3-319-63760-0
- ECDC, 2018: Field sampling methods for mosquitoes, sandflies, biting midges and ticks. European Centre for Disease Prevention and Control, Stockholm. https://www.ecdc.europa.eu/sites/default/files/documents/Vector-sampling-field-protocol-2018.pdf
- Fischer O., L. Mátlova, J. Bartl, L. Dvorská, I. Melichárek, I. Pavlík, 2000: Findings of mycobacteria in insectivores and small rodents. Folia Microbiologica 45 (2): 147–152. https://doi.org/10.1007/BF02817414
- Gebreyes, W.A., J. Dupouy-Camet,, M.J. Newport, C.J.B. Oliveira, L.S. Schlesinger, Y.M. Saif, W. Saville, T.E. Wittum, A.E. Hoet, S. Quessy, 2014: The global One Health paradigm: challenges and opportunities for tackling infectious diseases at the human, animal, and environment interface in low-resource settings. PLoS Neglected Tropical Diseases 8 (11): e3257. https://doi.org/10.1371/journal.pntd.0003257
- Hayasaka D., L. Ivanov, G.N. Leonova, A. Goto, K. Yoshii, T. Mizutani, H. Kariwa, I. Takashima, 2001: Distribution and characterization of tick-borne encephalitis viruses from Siberia and far-eastern Asia. Journal of General Virology 82 (6): 1319-1328. https://doi.org/10.1099/0022-1317-82-6-1319
- HZJZ, 2016: Krpelji i bolesti koje najčešće prenose u Hrvatskoj te preventivne mjere zaštite od krpelja. Hrvatski zavod za javno

zdravstvo. https://www.hzjz.hr/sluzba-epidemiologija-zarazne-bolesti/krpelji-i-bolesti-koje-najcesce-prenose-u-hrvatskoj-te-preventivne-mjere-zastite-od-krpelja/

- HZJZ, 2017: Godišnje izvješće o zoonozama u Hrvatskoj za 2015./16. godinu. Hrvatski zavod za javno zdravstvo. https://www.hzjz.hr/sluzba-epidemiologija-zarazne-bolesti/godisnje-izvjesce-o-zoonozama-u-hrvatskoj/
- Körner S., G.R. Makert, S. Ulbert, M. Pfeffer, K. Mertens-Scholz, 2021: The prevalence of *Coxiella burnetii* in hard ticks in Europe and their role in Q fever transmission revisited – A systematic review. Frontiers in Veterinary Science 8: 655715. https://doi.org/10.3389/fvets.2021.655715
- Krčmar, S., 2012: Hard ticks (Acari, Ixodidae) of Croatia. ZooKeys 234: 19–57. https://doi.org/10.3897/zookeys.234.3658
- Lee H.W., P.W. Lee, L.J. Baek, Y.K. Chu, 1990: Geographical distribution of hemorrhagic fever with renal syndrome and hantaviruses. In (Calisher, C.H., ed.): Hemorrhagic Fever with Renal Syndrome, Tick- and Mosquito-Borne Viruses. Archives of Virology Supplementum, vol. 1. Springer, Vienna. https://doi.org/10.1007/978-3-7091-9091-3_2
- Léger, E., G. Vourc'h, L. Vial, C. Chevillon, K.D. McCoy, 2013: Changing distributions of ticks: causes and consequences. Experimental and Applied Acarology 59 (1–2): 219–234. https://doi.org/10.1007/s10493-012-9615-0
- Liebisch, A., 1977: Das Q-Fieber als Naturherdinfektion in Süddeutschland. Bundesgesundheitsblatt 20: 185–191.
- Margaletić, J., 2006: Sitni glodavci kao rezervoari zoonoza u šumama Hrvatske. Radovi – Šumarski institut Jastrebarsko 41 (1–2): 133–140.
- Meerburg, B.G., G.R. Singleton, A. Kijlstra, 2009: Rodent-borne diseases and their risks for public health. Critical Reviews in Microbiology 35 (3): 221–230. https://doi.org/10.1080/10408410902989837
- Moj Tender, 2020: Istarska županija. https://moj-tender.hr/Istarska%20%C5%20županija/description-75.html
- Mulić, R., B. Petković, Z. Klišmanić, I. Jerončić, 2011: Bolesti koje prenose krpelji u Republici Hrvatskoj. Hrvatski časopis za javno zdravstvo 7 (28): 3–7.
- Mysterud, A., C. Hügli, H. Viljugrein, 2021: Tick infestation on medium–large-sized mammalian hosts: are all equally suitable to Ixodes ricinus adults? Parasites & Vectors 14 (1): 254. https://doi.org/10.1186/s13071-021-04775-6
- Olsson G.E., N. Whit, C. Ahlm, F. Elgh, A.C. Verlemyr, P. Juto, R.T. Ralo, 2002: Demographic factors associated with hantavieus infection in bank voles (*Clethrionomys glareolus*). Emerging Infectious Diseases 8 (9): 924–929. https://doi.org/10.3201/eid0809.020037
- NN 79/07: Zakon o zaštiti pučanstva od zaraznih bolesti, Narodne novine. https://narodne-novine.nn.hr/
- NN 42/13: Pravilnik o načinu praćenja zoonoza i uzročnika zoonoza. Narodne novine. https://narodne-novine.nn.hr/clanci/sluzbeni/2013_04_42_797.html
- NN 133/23: Pravilnik o načinu prijavljivanja zaraznih bolesti Ministarstvo zdravstva RH. Narodne novine. https://zdravlje.gov.hr/
- Račić, I., 2012: Genetička raznolikost bakterija Coxiella burnetii u Hrvatskoj. Doktorski rad, Sveučilište u Zagrebu Prirodoslovno-matematički fakultet, Zagreb. https://repozitorij.pmf.unizg.hr/
- Rauter, C., T. Hartung, 2005: Prevalence of *Borrelia burgdorferi* sensu lato genospecies in *Ixodes ricinus* ticks in Europe: a metaanalysis. Applied and Environmental Microbiology 71 (11): 7203–16. https://doi.org/10.1128/AEM.71.11.7203-7216.2005
- Reháček, J.L., 1977: Rickettsiae of the spotted fever group isolated from Dermacentor marginatus ticks in South Germany. Zentralblatt für Bakteriologie 239: 257–281.
- Reháček, J.U., 1992: Susceptibility of some species of rodents to rickettsiae. Folia Parasitologica 39: 265–284.
- Richter, B., 2002: Medicinska parazitologija. VI izmijenjeno i dopunjeno izdanje. A.B.D. Merkur, Zagreb.
- Rizzoli, A., C. Silaghi, A. Obiegala, I. Rudolf, Z. Hubálek, G. Földvári, O. Plantard, M. Vayssier-Taussat, S. Bonnet, E. Špitalská, M. Kazimírová, 2014: Ixodes ricinus and its transmitted pathogens in urban and peri-urban areas in Europe: new hazards and relevance for public health. Frontiers in Public Health 2: 251. https://doi.org/10.3389/fpubh.2014.00251
- Ropac, D.Š., 2019: Epidemiološke osobitosti lajmske bolesti u Republici Hrvatskoj u razdoblju od 2012. do 2016. godine. Acta Medica Croatica 73 (2): 151–158.
- Rowe, H.M., J.F. Huntley, 2015: From the Outside-In: The *Francisella tularensis* Envelope and Virulence. Frontiers in Cellular and Infection Microbiology 5: 94. https://doi.org/10.3389/fcimb.2015.00094
- Sameroff S., R. Tokarz, M. Vucelja, K. Jain, A. Oleynik, M. Boljfetić, L. Bjedov, R.A. Yates, J. Margaletić, C.A.L. Oura, W.I. Lipkin, L. Cvetko Krajinović, A. Markotić, 2022: Virome analysis of *Ixodes ricinus* ticks from Croatia. Viruses 14 (5): 929. https://doi.org/10.3390/v14050929
- Schmaljohn C.S., B. Hjelle, 1997. Hantaviruses: a global disease problem. Emerging Infectious Diseases 3 (2): 95–104. https://doi.org/10.3201/eid0302.970202
- Skar, G.L., K.A. Simonsen, 2024: Lyme disease. In: StatPearls [Internet]. Treasure Island (FL): StatPearls Publishing. https://www.ncbi.nlm.nih.gov/books/NBK431066/
- Stanek, G., G.P. Wormser, J. Gray, F. Strle, 2012: Lyme borreliosis. The Lancet 379 (9814): 461–473. https://doi.org/10.1016/S0140-6736(11)60103-7
- Stuen S., 2007: *Anaplasma phagocytophilum* - the most widespread tick-borne infection in animals in Europe. Veterinary Research Communications 31 (1): 79–84. https://doi.org/10.1007/s11259-007-0071-y
- Vilibić-Čavlek, T., L. Barbić, A. Mrzljak, D. Brnić, A. Klobučar, M. Ilić, N. Janev-Holcer, M. Bogdanić, L. Jemerišić, V. Stevanović, I. Tabain, S. Krčmar, M. Vucelja, J. Prpić, M. Boljfetić, P. Jeličić, J. Madić, I. Ferenčak, V. Savić, 2021: Emerging and neglected viruses of zoonotic importance in Croatia. Pathogens 10 (1): 73. https://doi.org/10.3390/pathogens10010073
- Vilibić-Čavlek, T., N. Janev-Holcer, M. Bogdanić, T. Ferenc, M. Vujica Ferenc, S. Krčmar, V. Savić, V. Stevanović, M. Ilić, Lj. Barbić, 2023: Current status of vector-borne diseases in Croatia: Challenges and future prospects. Life 13 (9): 1856. https://doi.org/10.3390/life13091856
- Vucelja, M., S. Krčmar, J. Habuš, V. Mojčec Perko, M. Boljfetić, L. Bjedov, J. Margaletić, 2023: Altitudinal distribution, seasonal dynamics and *Borrelia burgdorferi* sensu lato infections in hard ticks (Acari: Ixodidae) in different forest communities in Inland Croatia. Sustainability 15 (6): 4862. https://doi.org/10.3390/su15064862
- Vukelić, J., Đ. Rauš, 1998: Šumarska fitocenologija i šumske zajednice u Hrvatskoj. Šumarski fakultet Sveučilišta u Zagrebu, Zagreb.
- Zdolec, N., 2011: Jedno zdravlje. Meso: prvi hrvatski časopis o mesu 12: 386.

SUMMARY

Monitoring the presence of vectors of infectious diseases is of critical importance for public health protection and it further emphasizes the necessity of an interdisciplinary approach within the "One Health" concept. This study is based on field research of ticks as vectors of zoonotic pathogens and the analysis of tick-borne disease incidence in Istria County, Croatia. According to data from the Croatian Institute of Public Health for the period 2016–2022, a total of 126 cases of zoonotic diseases were reported, of which 114 (93.4%) were cases of Lyme borreliosis, two were cases of Q fever, and one case each of rickettsiosis and haemorrhagic fever with renal syndrome. Eight reported cases of zoonoses were recorded in non-residents of Istria County. As part of this research, systematic sampling of hard ticks (Acari: Ixodidae) was conducted from 2020 to 2023 using the flagging method and collection from the host, yielding a total of 2349 specimens belonging to 12 different species from the genera *Ixodes*, *Dermacentor*, *Hyalomma*, *Haemaphysalis*, and *Rhipicephalus*, along with one soft tick from the genus *Argas*. The dominant species was the sheep tick (*Ixodes ricinus* L.), accounting for 70.84% of the total sample. This species is a known vector of *Borrelia burgdorferi* sensu lato (the causative agent of Lyme borreliosis) and *Coxiella burnetii* (the causative agent of Q fever).

The results indicate a notable presence and wide distribution of vectors responsible for the transmission of Lyme borreliosis, confirmed as the most prevalent zoonosis in the region. The obtained data support the need for continuous entomological surveillance and epidemiological monitoring of vector-borne diseases to enable more accurate risk assessment and the development of appropriate public health measures.

KEY WORDS: Istria County, public health, ticks, Lyme disease, zoonoses

IZNIMNA STABLA NAŠIH ŠUMA

Lički car caruje u visinama Velebita - (ne)obična jela (*Abies alba* Mill.) iz Begovače

Mandica Dasović[1], Antonija Jurković-Tomac[2]

Časopis Šumarski list pokreće novu rubriku **Iznimna stabla naših šuma** u kojoj želimo predstaviti pojedinačna stabla u našim šumama koja se ističu visinom, prsnim promjerom, volumenom, dobi, habitusom, kvalitetom debla, rijetkom pojavom, posebnim nalazištem ili nekim drugim posebnim obilježjem. Pozivamo čitatelje da se uključe u kreiranje ove rubrike i pošalju nam fotografije i detaljniji opis takvih stabala u našim šumama.

Uredništvo

Žilište stabla - promjer stabla u prsnoj visini oko 190 cm.

Prelazeći preko znamenitog kosinjskog mosta i vozeći se kroz Gornji Kosinj i Kosinjski Bakovac, dolazi se u predio zvan Kotao. Taj dio Velebita znan je po prekrasnim šumama bukve i jele kojima gospodari UŠP Gospić, Šumarija Perušić, a obuhvaćen je Programom gospodarenja za gospodarsku jedinicu Konjska draga – Begovača, s planom upravljanja područjem ekološke mreže. U Parku prirode Velebit nalazi se 91 % površine ove gospodarske jedinice kao i sam predio Kotao u kojemu raste vjerojatno najveća jela u Hrvatskoj i Europi.

Šume Begovače od velikog su značenja za stanovništvo toga kraja. Iz tih šuma se drvarilo, sjekla se građa za kuće, ubirali šumski plodovi, odvodila stoka na ispašu … s tom šumom se živjelo. Volio je i čuvao narod svoju šumu, prepoznavao ona najljepša, najveća stabla oko kojih se okupljalo, sjedilo i pričalo, a upravo takvo je „Jela Car". Ova velebitska ljepotica dobi ime „Car", a ne carica ili kraljica kako bi priličilo stablu ženskoga roda, no u narodu je car predstavljao nekog vrlo moćnog, uzvišenog, velikog vladara, a ova jela je upravo to među svim drugim stablima na Velebitu. Davno je, ne zna se kada, dobila ime „Jela Car", koje s ponosom nosi i danas.

„Jela Car" najveće stablo obične jele (*Abies alba* Mill.) na Velebitu, raste na 924 metra nadmorske visine. Svojom impozantnom visinom od 47,5 metara i opsegom od 5,9 metara u prsnoj visini (prsni promjer 1,9 metra), nadvisuje sva okolna stabla. Starost joj nije utvrđivana ali je procijenjena na više od 500 godina.

Imala je ova jela, ovaj car od stabla i teških trenutaka. Jedan takav zbio se 1968. godine kada je u vrh stabla udario grom, nakon čega su se odlomile tri vršne grane i tek 1976. godine vrh se ponovno zazelenio od novih izbojaka.

PODACI IZMJERE

- visina stabla 47,5 m
- visina baze krošnje: 13,5 m
- opseg stabla u prsnoj visini 592 cm (promjer 189 cm)
- opseg stabla na visini 10 m iznosi 443 cm (promjer 141 cm)
- opseg stabla na visini 20 m iznosi 402 cm (promjer 128 cm)
- opseg stabla na visini 30 m iznosi 303 cm (promjer 97 cm)

Zahvaljujući želji, ali i potrebi da se o „Jeli Car" sazna što više, Park prirode Velebit proveo je istraživanje pod nazivom „Zdravstvena procjena stabla obične jele – jela car (*Abies alba*) u PP Velebit". Zahvaljujući tomu, dobiveni su podaci koji će uvelike pomoći u očuvanju i zaštiti ovog impozantnog stabla. Jedan ljudski život za ovu jelu ne znači puno, ali ako postoji i najmanja mogućnost poboljšanja životnih uvjeta za istu, ona bi se trebala ostvariti.

Ovim istraživanjem na zahtjev PP Velebit, u srpnju 2023. godine izvršen je zdravstveni pregled i ocjena vitalnosti te statičke sigurnosti stabla „Jele Car".

Rezultati procjene vitaliteta i zdravstvenog stanja

Pregled stabla poznat je pod nazivom VTA (eng. *Visual tree assesment*) analiza, uključujući izmjeru preostale

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[2] Antonija Jurković-Tomac, mag. ing. silv., Park prirode Velebit, Gospić

Na visini od 30 metara „Jela Car" izrasta iz sastojine i promjerom od 97 centimetara premašuje promjere koje okolna stabla imaju pri tlu.

čvrste drvne stijenke mjernim instrumentom rezistografom izvršila je Jana Nature Company 2023. godine. Zdravstveno stanje žilišta, pridanka i debla do baze krošnje pregledano je s tla, dok je utvrđivanje stanja krošnje i debla od baze krošnje sve do vrha stabla bilo potrebno provesti tehnikom penjanja.

Žilište stabla je vrlo razvedeno, a u nekoliko ogranaka žilišta prisutne su otvorene šupljine i truleži. Jedan ogranak žilišta zahvaćen je srednje jakom truleži, a za utvrđivanje njezine uznapredovalosti provelo se mjerenje preostale čvrste stijenke rezistografom. Uočeno je kako je razmjer truleži vrlo malen u odnosu na presjek debla te da se s porastom visine postupno smanjuje i pozicijom zakreće u smjeru obrnutom od kazaljke na satu, što znači da trulež prati prirodnu zakrivljenost žice debla. Na visini od 3,5 metra trulež više nije zabilježena. Mogući uzrok šupljina je mehanička ozljeda i one su konzistentno obrasle korom.

Autorica i Car.

Baza krošnje nalazi se na 13,5 metara visine, donji dio krošnje je vitalan, ali u samoj bazi nalaze se plodišta saprofitne gljive truležnice (red Aphyllophorales) locirane u pazušcu suhe grane. Penjući se dalje uočava se i rakasta tvorevina na jednoj od grana, a na 16,5 metara uočeni su simptomi djelovanja ksilofagnih kukaca iz porodice pipa (Curculioninae). Na visini od 23 metra uspravno uz deblo raste mlado debalce promjera 13 centimetara u bazi pršljena. Do visine 30 metara nisu uočene duplje niti šupljine kao niti „U" ili „V" rašlje. Na ovoj visini primjećuje se početak velike zastupljenosti bijele imele (*Viscum album* L.) koja se proteže do samog vrha krošnje. Suhe grane prisutne su cijelom visinom krošnje, a napredovanjem visine povećava se i količina lišajeva.

Na 42. metru nalazi se mjesto starog loma vrha krošnje nakon udara groma, a prisutna je i centralna trulež.

Iznad mjesta loma razvili su se novi vrhovi visine oko 5 metara, koji nisu bili sigurni za penjanje. Unutar mjesta starog loma krošnje stvorila se šupljina u deblu dubine oko 40 centimetara.

Nakon ovog pregleda, zaključak je kako je „Jela Car" dobrog zdravstvenog stanja i ima dobru razinu statike.

Sve se češće oko jele okupljaju ljubitelji Velebita i oni koji prepoznaju njenu vrijednost i posebnost. To potvrđuju i dva puta održane kulturno – zabavne manifestacije Mirakul na Velebitu – „U zagrljaju Jele Car".

Zaslužuje taj lički Car svojom višestoljetnom vladavinom veliku pozornnost i zaštitu, kako bi još dugo, dugo i dalje svjedočio zbivanjima u šumama Velebita.

Štete od srpanjskog nevremena 2023. godine

Krešimir Žagar[1]

Vratimo se malo na početak 2023. šumarske poslovne godine. Krenulo se s dinamičkim izvršavanjem plana proizvodnje, slijedilo je suočavanje s već poznatim izazovima kao što su nedostatak radne snage, praćenje pojave hrastove mrežaste stjenice, sanacija jasenovih sastojina napadnutih halarom, suočavanje s problematikom višegodišnjeg slabog uroda žira. Vremenske prilike zbog učestalih kišnih padalina utjecale su na gubitak desetaka radnih dana i zaostajanje u proizvodnji drvnih sortimenata, a početkom ljeta pojavila se i afrička svinjska kuga.

No u mjesecu srpnju uslijedilo je ono po čemu će sva hrvatska, posebice šumarska javnost, pamtiti 2023. godinu.

Devetnaestog dana srpnja 2023. godine u popodnevnim satima ogromno područje Hrvatske, od granice sa Slovenijom na zapadu, pa do granice sa Srbijom na istoku, zahvatilo je olujno nevrijeme neviđenih razmjera i snage. Olujni vjetar koji je puhao brzinom od 100-180 km/h prouzročio je enormne štete na objektima, infrastrukturi, kao i na poljoprivrednim površinama i šumskim sastojinama. Nažalost oluja je bila i smrtonosna jer su tom prilikom izgubljena tri ljudska života. Okolnost da se oluja događala u popodnevnim i večernjim satima utjecala je na to da su izbjegnute veće žrtve, jer se u šumi u to vrijeme više nisu nalazili šumarski djelatnici. Nažalost oluja je, ipak nešto slabijih razmjera, ponovno pogodila istok Hrvatske i dva dana kasnije, 21. srpnja i prouzročila dodatne štete.

Najveća šteta nastala je na krajnjem istoku Hrvatske,

gdje je snaga i brzina vjetra dosegla svoj maksimum, a najveće štete nastale su upravo na šumskim sastojinama.

Iste noći nakon prolaska oluje, pa sve do sredine kolovoza 2023. godine djelatnici i vozila te strojevi Hrvatskih šuma d.o.o. kao jedna od glavnih operativnih snaga uz civilnu zaštitu, vojsku i komunalne službe, pružali su ispomoć na uklanjanju posljedica nevremena na državnim, županijskim, lokalnim i nerazvrstanim prometnicama te privatnim i javnim objektima i infrastrukturi. Tek nakon toga krenulo se s raščišćavanjem šumskih prometnica, kako bi se napokon pristupilo pogođenim šumskim područjima. Na temelju snimaka iz dronova te usporedbom stanja prije i nakon oluje, na satelitskim snimkama već je bila izvršena preliminarna procjena štete. Nevjerojatni prizori štete na terenima na koje je bilo moguće pristupiti ledili su krv u žilama i izazivali nevjericu i zaprepaštenje naših kolega. Nije se gubilo vrijeme i promptno se krenulo s doznačivanjem i evidentiranjem vjetrom izvaljenih i polomljenih stabala te sanacijom oštećenih sastojina.

[1] **mr. sp.** Krešimir Žagar, dipl. ing. šum., Hrvatske šume d.o.o.

uprava šuma podružnica	ukupna šteta	hrast lužnjak	hrast kitnjak	bukva	jela/smreka	ostale vrste
VINKOVCI	2.800.000	2.143.000				657.000
OSIJEK	29.264	602	200	200		28.262
POŽEGA	247.756	4.051	89.999	118.580	9.190	25.936
BJELOVAR	287.169	48.931	46.424	111.336	3.955	76.523
KOPRIVNICA	10.678	2.281	499	2.293	30	5.575
ZAGREB	332.312	98.052	46.417	54.263	2.151	131.429
KARLOVAC	7.999	360	1.387	5.065	104	1.084
SENJ	35.993			7.669	28.324	
GOSPIĆ	20.696			10.866	9.743	87
BUZET	18.601			17.165	179	1.257
NOVA GRADIŠKA	631.076	107.737	142.274	283.148	17.488	80.429
UKUPNO	**4.421.544**	**2.405.014**	**327.200**	**610.585**	**71.164**	**1.007.582**

U tablici je prikazana ukupna šteta na bruto drvnoj zalihi u državnim šumama kojima gospodare Hrvatske šume d.o.o., a koja je procijenjena na više od 4,4 milijuna m^3.

Najveća šteta nastala je na području UŠP Vinkovci i to bruto 2,8 milijuna m^3 (od toga preko 2,1 milijun m^3 hrasta lužnjaka) što iznosi oko neto 2 milijuna m^3 drvnih sortimenata.

Na temelju dogovora Uprave Hrvatskih šuma i resornog ministarstva Vlada RH je već 31. 8. 2023. godine donijela Uredbu o izmjenama i dopunama Zakona o šumama, a Ministarstvo poljoprivrede promptno je isti dan na temelju Uredbe donijelo i Naredbu o zabrani radova gospodarenja u određenim odsjecima kojima istječe šumskogospodarski plan, a kako se ne bi bespotrebno sjeklo svježa stabla te na taj način spriječilo nastajanje većih šteta i problema.

Hrvatske šume d.o.o. su na temelju Naredbe i stanja na terenu napravile rebalans plana proizvodnje drvnih sortimenata za 2023. godinu i pokrenule hitnu doznaku i evidentiranje vjetrom izvaljenih i oštećenih stabala.

Doznaku su vršili vlastiti radnici UŠP koje su pretrpjele štete, a u UŠP Vinkovci i Nova Gradiška, gdje su razmjeri štete bili takvi da se nije mogla izvršiti doznaka i evidentiranje štete vlastitim radnicima, u ispomoć su stigli diplomirani inženjeri šumarstva, poslovođe i šumski radnici iz svih ostalih podružnica.

Paralelno je krenula i hitna sanacija, odnosno sječa i izrada te privlačenje i izvoženje drvnih sortimenata pomoću vlastitih kapaciteta (domicilne UŠP uz ispomoć svih ostalih UŠP u F1 i F2) te kapaciteta poduzetnika putem ugovora na temelju provedenih postupaka kroz dinamički sustav javne nabave. Prethodno su sa svim poduzetnicima, a koji su imali već ugovorene radove i koji su bili spremni vršiti sanaciju vjetroizvala i vjetroloma, sporazumno raskinuti aktivni ugovori ili su dodatkom ugovora prolongirani rokovi izvođenja tih ugovora. Izrada drvnih sortimenata pri sanaciji vjetroloma i vjetroizvala je za sjekače izuzetno opasan i težak posao, pri čemu je potrebno iznimno oprezno izvođenje radova, a maksimalno su korišteni harvesteri i žičare s harvesterskom glavom.

Najprije se krenulo u sanaciju najstarijih oštećenih sastojina u kojima su se nalazila najkvalitetnija stabla, kako bi se maksimalno iskoristili najvrjedniji sortimenti i time umanjila nastala šteta.

Do kraja 2024. godine praktički je završila sanacija na svim olujom pogođenim UŠP, osim u Vinkovcima gdje je nastala najveća šteta, i to 63 % ukupne štete, a zbog stradanja hrasta lužnjaka po vrijednosti i 80 % i gdje je logično bio i fokus sanacije. Tako je do kraja 2023. godine samo na području UŠP Vinkovci sanitarnom sječom i izradom drvnih sortimenata proizvedeno 310.000 m^3 drvnih sortimenata, a tijekom 2024. godine 1.185.000 m^3, a do sada u 2025. godini proizvedeno je gotovo 500.000 m^3 drvnih sortimenata.

Procjenjuje se da je za sanaciju u UŠP Vinkovci preostalo oko 200.000 m^3 bruto drvne mase, iz čega bi se moglo proizvesti još oko 150.000 m^3 sada već daleko manje vrijednih drvnih sortimenata.

Ukupno je na području UŠP Vinkovci do današnjeg dana, u razdoblju od 19. 7. 2023. do 25. 11. 2025. godine sanitarnom sječom i izradom drvnih sortimenata sanirano oko 2,6 milijuna m^3 bruto drvne mase (93 % od oštećenih 2,8 milijuna m^3) iz čega je proizvedeno gotovo 2,0 milijuna m^3 drvnih sortimenata, a od toga 970.000 m^3 furnirskih i pilanskih trupaca te 1.000.000 m^3 prostornog (ogrjevnog) drveta.

Sanacija samih staništa koja su ostala bez šumskog pokrova izazov je za sljedeće desetljeće. Naime, bit će potrebno izvršiti pošumljavanje tisuća hektara površina, čemu je prethodila sanacija vjetroizvala i uspostava šumskog reda te priprema staništa. Neredoviti urod žira utjecat će na proizvodnju potrebnog sadnog materijala, a kad se i proizvede potrebno je izvršiti sadnju u optimalnom razdoblju godine u vrijeme mirovanja vegetacije kad je najveće opterećenje lošim vremenskim uvjetima, a uz sve to prisutan je nedostatak radne snage potrebne za obavljanje ovog obimnog i teškog posla.

Sanacija je započela već krajem 2023. i početkom 2024. godine, a prošle godine je iskorišten i napokon dobar urod žira hrasta lužnjaka i dio stradalih površina sanirao se, osim sadnjom sadnica, i sjetvom žira.

Slijede nam godine intenzivne brige, zaštite i njege pomlatka i budućih mladih sastojina.

Svjesni smo da će biti potrebna desetljeća da se staništa saniraju, no posljedice srpanjske oluje iz 2023. godine, posebice na području Spačvanskog bazena, bit će vidljive stoljećima.

Sedmi hrvatski znanstveno-stručni skup o urbanom šumarstvu, Vinkovci 2025.

Damir Dramalija[1]
fotografije: Damir Dramalija, Lucija Vargović, grad Vinkovci

Nakon uspješno održanog skupa u Opatiji prošle godine, treba istaknuti zadovoljstvo svih organizatora što se ovaj događaj, u skladu sa ustaljenom praksom promjene domaćina, ponovo vratio u Slavoniju, gdje je u Osijeku 2019. prvi puta organiziran.

Ovogodišnji, 7. hrvatski znanstveno-stručni skup o urbanom šumarstvu, s glavnom temom: „Izazovi urbanog šumarstva u prilagodbi na klimatske promjene“, održan je 16. i 17. listopada 2025. godine u Vinkovcima. Organizatori skupa bili su Sveučilište u Zagrebu Fakultet šumarstva i drvne tehnologije, Hrvatske šume d.o.o. Zagreb, Hrvatski šumarski institut i Hrvatsko šumarsko društvo - Sekcija za urbano šumarstvo sa suorganizatorima Akademijom šumarskih znanosti te Hrvatskom komorom inženjera šumarstva i drvne tehnologije, a sve uz pokroviteljstvo Vukovarsko-srijemske županije i Grada Vinkovaca. Važno je istaknuti da ovaj skup predstavlja i jednu od aktivnosti kojima se obilježava 260 godina organiziranog šumarstva u Hrvatskoj, čijem su razvoju Vinkovci i cijela Slavonija dali izuzetan doprinos.

Grad Vinkovci prepoznat je kao grad u kojemu se cijeni značaj i velika vrijednost urbanih šuma i u kojemu se kvalitetno skrbi o urbanom drvenastom zelenilu. Potvrda toga su sjajni parkovi kao što su Gradski park Vinkovci, Park Lenije i novoizgrađeni Park Papuk te park-šume Kanovci, Kunjevci i Zvirinac. Također, nemoguće je ne spomenuti da su Vinkovci najstariji grad u Europi neprekidno naseljen preko 8200 godina i za pretpostaviti je da su njegovi stanovnici oduvijek živjeli uz šumu, koristeći neke od njenih dobrobiti. Isto tako, potrebno je istaći da cijela Vukovarsko-srijemska županija ima razvijenu zelenu infrastrukturu sa značajnim prirodnim kompleksima, od kojih su mnogi zaštićeni te predstavljaju istinske prirodne znamenitosti, zbog čega su uključeni u veliku europsku ekološku mrežu Natura 2000. Uz već navedenu park-šumu Kanovci, treba istaknuti i područja kao što su Vukovarske dunavske ade, zaštićeni hrastovi u Drenovcima, te park oko dvorca u Nuštru i park oko starog grada u Iloku.

Kao i prijašnjih godina, prije samog otvorenja skupa, organizirana je prigodna sadnja ukrasnog drveća kojom se na simboličan način obilježava održavanje skupa, a u kojoj je sudjelovao i gradonačelnik Grada Vinkovaca g. Josip Romić. Na zelenoj površini ispred Centra za socijalnu skrb u Vinkovcima, posađene su tri parkovne sadnice oskoruše (*Sorbus domestica*). Oskoruša je odabrana jer se radi o našoj autohtonoj vrsti šumske voćkarice koja je vrlo dekorativna, doprinosi bioraznolokosti i dobro podnosi teške uvjete urbane sredine.

Na zadovoljstvo domaćina i organizatora skupa, u suvremeno uređenoj Velikoj vijećnici Vukovarsko-srijemske županije u Vinkovcima, okupilo se

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rekordnih 150 znanstvenika i stručnjaka iz tvrtki, institucija i ustanova iz područja urbanoga šumarstva i povezanih djelatnosti iz cijele Hrvatske. U takvom pozitivnom ozračju, znanstveno-stručni skup otvorili su pozdravnim govorima Krasnodar Sabljić, Voditelj vinkovačke podružnice Hrvatskih šuma, Martina Kičić, predstavnica Hrvatskog šumarskog instituta, Darko Posarić, dopredsjednik Hrvatskog šumarskog društva, prof. dr. sc. Marijan Grubešić - predsjednik Akademije šumarskih znanosti, Hrvoje Niče, pročelnik Upravnog odjela gospodarstva Grada Vinkovci, Silvija Šokčević u ime Vukovarsko-srijemske županije i JU Priroda i prof. dr. sc. Josip Margaletić - dekan Fakulteta šumarstva i drvne tehnologije Sveučilišta u Zagrebu.

U dva dana rada skupa, moglo se čuti 27 kvalitetnih prezentacija raspoređenih u pet tematskih cjelina. To su valorizacija i gospodarenje urbanim šumskim ekosustavima, upravljanje zaštićenim dijelovima prirode u urbanim područjima, održavanje urbanog drvenastog zelenila i urbanih šuma, socijalni segment urbanog šumarstva te uloga javnih politika u planiranju i izvođenju radova iz urbanog šumarstva i zelene infrastructure. Pojedine sesije redom su moderirali prof. dr. sc. Stjepan Posavec, izv. prof. dr. sc. Vinko Paulić, prof. dr. sc. Željko Škvorc i Damir Dramalija, dipl. ing. šum.

Očekivano, veliki interes su izazvala predavanja vezana uz naslovnu temu koja je odabrana u skladu s aktualnim trenutkom u kojem cijeli svijet ulaže iznimne napore u borbi protiv klimatskih promjena. Niz postavljenih pitanja autorima prezentacija, ali i svim nazočnima, rezultirao je konstruktivnom raspravom i razmjenom mišljenja. Tako su razmotreni neki od izazova u tom procesu prilagodbe koji stoje pred svima uključenim u skrb o urbanim šumama i urbanom drvenastom zelenilu u ovom interdiciplinarnom području.

Isto tako, posebno zanimanje izazvale su prezentacije koje se bave problematikom zakonskog pozicioniranja urbanog šumarstva, kao i nedostatkom odgovarajućih zakonskih rješenja vezanih za upravljanje zelenim površinama. Tom prilikom je zaključeno da treba osnažiti rad radne skupine za zakonodavstvo unutar Sekcije, te joj priključiti zainteresirane predstavnike pravne struke.

Prezentacijski dio skupa završen je izlaganjima studenata urbanog šumarstva, zaštite prirode i okoliša koji su i ovom prilikom potvrdili svoje sposobnosti i kompetencije za kvalitetan i odgovoran rad u ovom sektoru.

Prema ustaljenoj praksi, prije službenog zatvaranja 7. hrvatskog znanstveno-stručnog skupa o urbanom šumarstvu, Vinkovci 2025., izv. prof. dr. sc. Vinko Paulić iznio je zaključke nastale iz programa rada skupa, uz uvažavanje svih prijedloga iznesenih u raspravama i razmjeni mišljenja i iskustava.

ZAKLJUČCI 7. HRVATSKOG ZNANSTVENO-STRUČNOG SKUPA O URBANOM ŠUMARSTVU, VINKOVCI 2025.

Tijekom 7. hrvatskog znanstveno-stručnog skupa o urbanom šumarstvu slušatelji su imali priliku čuti niz zanimljivih predavanja koja ističu ključne poruke povezane s ovogodišnjom temom skupa: prilagodbom urbanog šumarstva klimatskim promjenama. Ipak, tematska područja koja su predstavljena na skupu nadilazila su naslovnu temu, obuhvaćajući i druge važne aspekte ovoga područja.

Opći zaključci skupa ističu važnost urbanog šumarstva i urbanih šuma kao ključnih elemenata u prilagodbi na klimatske promjene, čime se ovome području dodaje sve veći značaj unutar šumarske struke. Posebno su naglašeni interdisciplinarni pristupi kao ključ za razumijevanje složenih izazova, poput klimatskih promjena. Potrebna je snažnija integracija znanstvenih spoznaja u javne politike kako bi se implementirala rješenja zasnovana na stručnom konsenzusu.

Sudionici su ukazali na važnost znanstvene komunikacije između različitih struka i uključivanje stručnjaka urbanog šumarstva u procese donošenja odluka o prilagodbi klimatskim promjenama u urbanim i periurbanim sredinama, kao i drugim pitanjima vezanim za drvenastu vegetaciju kao dio zelene infrastrukture.

Kroz predavanja je dodatno naglašena važnost interdisciplinarnosti i komunikacije s građanima. Primjerice, pri izgradnji novih sadržaja poput biciklističkih staza, nužno je kontinuirano educirati građane, projektante i investitore o integrativnom pristupu i biokulturnoj etici urbanog šumarstva. Time se može smanjiti šteta od uklanjanja stabala i degradacija javnih zelenih površina tijekom izgradnje, jer se cjelokupni proces izgradnje biciklističkih staza najčešće percipira kao isključivo pozitivna mjera održivosti (Vizentaner, J.). Unatoč podršci zelenim politikama, primjećuje se pad udjela zelenih površina, parkova i urbanih šuma u prostornim planovima. Zbog klimatskih promjena, europskih direktiva i koristi zelenila za zdravlje ljudi, nužno je izraditi prijedloge zakonskih izmjena koji bi omogućili razvoj i održavanje zelenih kvartova i gradova (Gjurkin, V.). Istraživanja informiranosti hrvatskih građana pokazuju da su ispitanici većinom zabrinuti za zdravlje stabala u urbanim sredinama, osviješteni o utjecaju bolesti i štetnika, najviše podržavaju preventivne i biološke mjere kontrole, te su većinom izrazili spremnost na primjenu preventivnih mjera protiv širenja bolesti i štetnika tzv. biosigurnosno ponašanje (Krajter Ostoić, S.). Šume koje se koriste za odmor i rekreaciju građana diljem Hrvatske važan su dio urbane zelene infrastrukture, stoga se treba čuvati njihova kvaliteta te naglašavati općekorisne funkcije koje pružaju društvu danas i u budućnosti (Kičić, M.). U tom smislu se ističe potreba daljnjeg zakonskog definiranja različitih kategorija šuma u urbanom području i rješavanje imovinsko-pravnih odnosa, kako bi omogućili njihovo ujednačenije gospodarenje i uređenje (Kosijer Gorički, D.).

Daljnji razvoj područja urbanog šumarstva vidimo kroz integraciju stručnog znanja iz područja šumarstva, suvremenih tehnologija, financijskih sredstava EU fondova i sudjelovanja građana, čime se može uspostaviti inovativan, održiv i uključiv model upravljanja urbanim šumama koji doprinosi očuvanju bioraznolikosti, povećanju otpornosti na klimatske promjene i unaprjeđenju kvalitete života u urbanim sredinama (Franjić, I.).

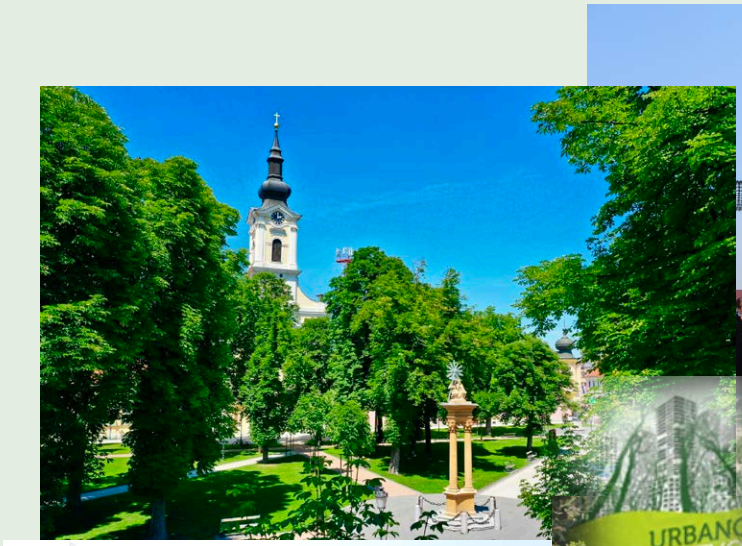
Preporuke za daljnji razvoj područja uključuju poticanje interdisciplinarnih istraživačkih projekata u okviru nacionalnih i europskih fondova, s fokusom na jačanje zakonodavnog položaja urbanog šumarstva. Također, potrebno je unaprijediti obrazovanje i širenje znanstvenih te stručnih spoznaja kroz suradnju unutar i izvan šumarske struke.

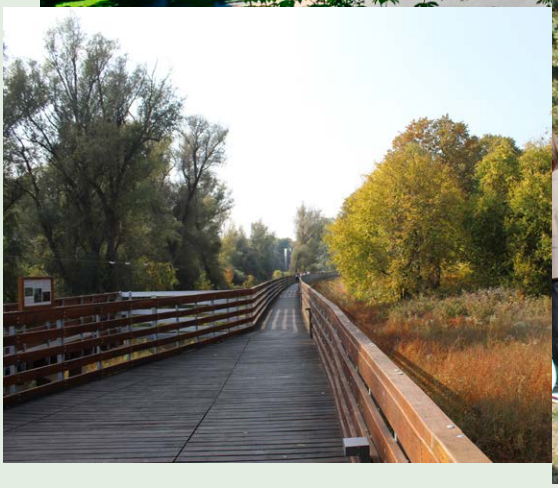
Posebnu pozornost treba usmjeriti na digitalne tehnologije koje omogućuju praćenje i evaluaciju zelene infrastrukture, s naglaskom na urbano drvenasto zelenilo. Poticanje razvoja platformi za suradnju različitih dionika — od znanstvene zajednice, stručnjaka, donositelja odluka do šire javnosti — ključno je za daljnji održivi razvoj urbanog šumarstva i zelene infrastrukture u cjelini.

Tradicionalno, organizirane su i terenske aktivnosti od kojih treba izdvojiti obilazak Velikog parka u središtu Vinkovaca i parka Papuk koji je sjajan primjer uspješne sanacije odlagališta otpada, uz stručno vodstvo g. Josipa Barišića iz Agencije za razvoj i investicije Grada Vinkovaca VIA d.o.o. Drugi dan, organiziran je posjet atraktivnoj park-šumi Adica u Vukovaru, gdje je kolega Ivan Prebanić, upravitelj Šumarije Vukovar, na zanimljiv i stručan način predstavio aktivnosti vezane uz održavanje i razvoj ove tražene destinacije i opisao primjere dobre prakse suradnje Hrvatskih šuma i Grada Vukovara. Nakon toga, sudionici skupa posjetili su neke od značajnih lokacija iz Domovinskog rata u Vukovaru, našem gradu-heroju, i time na dostojanstven način završili još jedan skup o urbanom šumarstvu.

Na kraju, organizatori skupa, Hrvatsko šumarsko društvo - Sekcija za urbano šumarstvo, Sveučilište u Zagrebu Fakultet šumarstva i drvne tehnologije, Hrvatski šumarski institut i Hrvatske šume d.o.o. Zagreb, izrazili su veliku zahvalnost pokroviteljima skupa Vukovarsko-srijemskoj županiji i Gradu Vinkovcima, kao i suorganizatorima, Akademiji šumarskih znanosti te Hrvatskoj komori inženjera šumarstva i drvne tehnologije, čiji je doprinos omogućio održavanje skupa. Posebna zahvala upućena je djelatnicima UŠP Vinkovci i članovima HŠD ogranak Vinkovci, koji su svojim zalaganjem i poznatom slavonskom gostoljubivošću osigurali visoko profesionalnu razinu cijelog događaja, ali i druženje i razmjenu iskustava izvan službenog protokola. Isto tako, velika zahvala upućena je svim autorima koji su uložili svoje vrijeme, znanje i iskustvo u pripremu stručnih i zanimljivih prezentacija, kao i svima ostalima bez čije nazočnosti ovaj skup ne bi uspio.

U skladu s općim zaključkom skupa da urbano šumarstvo i urbane šume u najširem smislu riječi imaju nezaobilaznu ulogu u nastojanjima za iznalaženje načina za ublažavanje posljedica klimatskih promjena u urbanim i periurbanim područjima, naglašeno je da će Sekcija za urbano šumarsto HŠD sa svim partnerima, ustrajno nastaviti s aktivnostima koje bi trebale dodatno pomoći prepoznatljivosti ovog, sve značajnijeg dijela šumarske struke.






1850
Hrvatskoga šumarskog društva
1950
Šumarskog lista
godina
Sretan Božić
i nova 2026. godina.

Obilježen Dan urbanog šumarstva u Hrvatskoj

Damir Dramalija[1]
fotografije: Damir Dramalija, Marija Glavaš, Dorica Matešić

Urbane šume i drvenasto zelenilo u gradskim sredinama predstavljaju neprocjenjivo prirodno bogatstvo, koje svojim općekorisnim funkcijama značajno doprinosi kvaliteti života građana. U uvjetima ubrzanog urbanog razvoja, rastućeg zagađenja životnog okoliša, značajnog povećanja broja stanovnika u gradovima, socijalne otuđenosti te sve primjetnijih posljedica klimatskih promjena, njihova uloga postaje važnija nego ikada.

Međutim, potrebno je naglasiti da se urbane šume suočavaju s brojnim izazovima – od zagađenja i nepovoljnih uvjeta za rast i razvoj, preko nedostatnih sredstava za održavanje i tzv. razvojnih pritisaka do nedovoljnog razumijevanja javnih politika i dijela građana o dobrobitima koje pružaju urbane šume. Stoga je nužno sustavno planiranje, primjena europskih standarda za sadnju i njegu stabala te aktivno uključivanje kako stručne, tako i najšire javnosti.

Kako bismo istaknuli značaj urbanih šuma i potaknuli svijest o potrebi njihove zaštite i održavanja, obilježavamo 15. studenoga kao Dan urbanog šumarstva u Hrvatskoj, koji je, na inicijativu Sekcije za urbano šumarstvo, Upravni odbor Hrvatskog šumarskog društva proglasio na svojoj 3. sjednici održanoj 9. prosinca 2022. Izabran je taj datum u spomen na 15. studeni 2019. kada je u Osijeku održan 1. hrvatski stručni skup o urbanom šumarstvu.

Nažalost, Dan urbanog šumarstva u Hrvatskoj još uvijek je dosta nepoznat široj javnosti, ali zahvaljujući entuzijazmu kolega koji prepoznaju značaj urbanog drvenastog zelenila u svakodnevnom životu gradskog stanovništva, organiziran je niz zanimljivih, poučnih i korisnih događanja.

Već poslovično, karlovački i virovitički šumari dali su svoj obol u obilježavanju toga datuma.

Tako je HŠD Ogranak Karlovac organizirao edukativnu šetnju „Pod krošnjama grada" koju je vodio inženjer šumarstva Marko Ožura, gdje je petnaestak zainteresiranih građana prošetalo karlovačkim parkovima. Posjetitelji su mogli saznati više o vrstama drveća koje rastu u gradu, o njihovoj zaštiti, održavanju i obnovi te važnosti za sam Karlovac. Šetnja je započela na Šetalištu dr. Franje Tuđmana, a prema željama sudionika završila je nakon skoro dva sata u Vrbanićevom perivoju.

[1] Damir Dramalija, dipl. ing. šum.,Hrvatsko šumarsko društvo

Važnost edukacije od najranije dobi prepoznali su članovi HŠD ogranak Virovitica te u suradnji sa Šumarijom Suhopolje, Općinom Suhopolje i OŠ Suhopolje, organizirali prigodnu akciju sadnje sadnica i uljepšavanja okoliša OŠ Suhopolje. Više detalja o toj hvalevrijednoj akciji možete pronaći na web stranici www.icv.hr.

Na inicijativu Sekcije za urbano šumarstvo HŠD, a kroz partnerstvo Hrvatskih šuma UŠP Zagreb i Grada Zagreba, projektirana je prva poučna staza urbanog šumarstva u Republici Hrvatskoj, koja je u sklopu obilježavanja Dana urbanog šumarstva svečano otvorena 21. studenog 2025. na području urbane šume Jelenovac u Zagrebu. Kao predstavnici partnera koji su sudjelovali u realizaciji ovoga projekta, okupljenima su se obratili Damir Miškulin, voditelj UŠP Zagreb, Vlasta Ranogajec, pomoćnica pročelnika za poljoprivredu, šumarstvo i lovstvo u Gradu Zagrebu te Damir Dramalija, predsjednik Sekcije za urbano šumarstvo HŠD. Nakon toga, svi navedeni govorili su u emisiji „Patrola" Zabavnog radija o značaju urbanih šuma i urbanog šumarstva, kao i o izazovima s kojima se suočavaju urbane šume i urbani šumari pri njihovoj obnovi i održavanju.

U godini u kojoj se obilježava 260. obljetnica organiziranog šumarstva u Hrvatskoj, otvorenje ove poučne staze s učionicom na otvorenom, simboličan je doprinos promociji urbanog šumarstva kao sve značajnijeg dijela šumarske struke. Također, jedan od ciljeva je potaknuti građane, lokalne vlasti i stručnjake na zajedničku brigu o zelenim površinama koje su temelj zdravog i održivog urbanog života. Ne treba posebno naglašavati da u tome edukacija svih dionika, od neposrednih korisnika usluga koje pružaju stabla u gradovima, preko vlasnika i upravitelja urbanog drvenastog zelenila, do samih izvođača radova, ima posebnu ulogu.

Za očekivati je da će lokalne škole i dječji vrtići prepoznati ovaj prostor kao pogodno mjesto za održavanje nastave u prirodi, posebice kroz već etabliranu radionicu Hrvatskih šuma „Škola u šumi, šuma u školi" koju je priznalo Ministarstvo znanosti i obrazovanja.

Sekcija za urbano šumarstvo HŠD izražava nadu da će se u nadolazećem vremenu još veći broj jedinica lokalne samouprave i njihovih komunalnih poduzeća, odgojno-obrazovnih ustanova, udruga građana te šumarskih i srodnih organizacija i institucija diljem Hrvatske uključiti u prigodno obilježavanje Dana urbanog šumarstva, kako bi isto u potpunosti zaživilo i kako bi svi zajedno širili poruku o značaju urbanih šuma i urbanog drvenastog zelenila u poznatim okolnostima klimatskih promjena i sve težih uvjeta za život u gradovima.

ZAPISNIK

2. SJEDNICE UPRAVNOG ODBORA HŠD 2025. GODINE ODRŽANE 27. STUDENOG 2025. U ŠUMARSKOM DOMU U ZAGREBU S POČETKOM U 11:15.

Nazočni članovi Upravnog odbora: akademik Igor Anić (predsjednik), Emil Balint, dipl. ing. šum., Daniela Cetinjanin, dipl. ing. šum., mr. sp. Mandica Dasović (dopredsjednica), mr. sc. Damir Delač, Damir Dramalija, dipl. ing. šum., Anto Glavaš, dipl. ing. šum., mr. sp. Tihomir Pejnović (umjesto Gorana Gopca, dipl. ing. šum.), mr. sc. Goran Gregurović, prof. dr. sc. Marijan Grubešić, prof. dr. sc. Marilena Idžojtić, Marina Juratović, dipl. ing. šum., Josip Kovačić, dipl. ing. šum., Ivan Krajačić, dipl. ing. šum., Valentina Kulaš, dipl. ing. šum., Predrag Magdić, dipl. ing. šum. (umjesto Dorice Matešić, dipl. ing. šum.), izv. prof. dr. sc. Stjepan Mikac, Darko Mikičić, dipl. ing. šum., Krešimir Pavić, dipl. ing. šum., Martina Pavičić, dipl. ing. šum., doc. dr. sc. Sanja Perić, Darko Posarić, dipl. ing. šum. (dopredsjednik), Ante Šimić, dipl. ing. šum., mr. sc. Dalibor Tonc, Davor Topolnjak, dipl. ing. šum., Dražen Zvirotić, dipl. ing. šum. i Silvija Zec, dipl. ing. šum.– ukupno 27

Ostali nazočni: Mario Bošnjak, dipl. ing. šum. (član Nadzornog odbora), Branko Meštrić, dipl. ing. šum. (član Nadzornog odbora), Oliver Vlainić, dipl. ing. šum. (tajnik), Biserka Marković, dipl. oec. (voditeljica računovodstveno-financijskih poslova) i Damjan Metličić, dipl. ing. šum. (tajnik Ogranka „Dalmacija" Split) – ukupno 5

Ispričani: mr. sc. Boris Belamarić, David Crnić, dipl. ing. šum., Goran Gobac, dipl. ing. šum., prof. dr. sc. Boris Hrašovec, Krešimir Jakupak, dipl. ing. šum., prof. dr. sc. Vladimir Jambreković, Damir Miškulin, dipl. ing. šum., prof. dr. sc. Ivica Tikvić, izv. prof. dr. sc. Dinko Vusić, Goran Bukovac, dipl. ing. šum. (predsjednik Nadzornog odbora) i Davor Prnjak, dipl. ing. šum. (član Nadzornog odbora) – ukupno 11

Sveukupno nazočnih: 32

Dnevni red:

1. Ovjera zapisnika 1. sjednice Upravnog odbora HŠD 2025. godine (objavljen u Šumarskom listu 5-6/2025)
2. Obavijesti
3. Aktualna problematika
4. Rebalans financijskog plana HŠD za 2025. godinu
5. Šumarski list i ostale publikacije
6. Pripreme za 129. redovitu sjednicu Skupštine HŠD
7. Program rada i financijski plan HŠD za 2026. godinu
8. Pripreme za obilježavanje 180 godina HŠD i 150 godina Šumarskog lista
9. Pitanja i prijedlozi.

Dnevni red jednoglasno je usvojen.

Ad 1. Ovjera zapisnika 1. sjednice Upravnog odbora HŠD 2025. godine (objavljen u Šumarskom listu 5-6/2025)

Zapisnik 1. sjednice Upravnog odbora HŠD 2025. godine jednoglasno je usvojen bez primjedbi.

Ad 2. Obavijesti

Predsjednik Igor Anić prezentirao je obavijesti od 1. sjednice UO HŠD održane 23. svibnja 2025. U pojedinim obavijestima dopune su davali posredni ili neposredni sudionici navedenih događanja koji se u obavijestima navode u zagradi.

- 3. – 7. lipnja 2025. – U Zürichu u Švicarskoj održan je Europski forum o urbanom šumarstvu (EFUF) 2025. s glavnom godišnjom skupštinom Udruge EFUF. Hrvatska predstavnica bila je dr. sc. Silvija Krajter Ostoić iz Hrvatskoga šumarskog instituta. (Damir Dramalija)
- 11. – 13. lipnja 2025. – U posjeti Hrvatskoj bili su zaposlenici mađarske šumarske tvrtke Pilisi Parkerdő d.o.o. koja gospodari državnim šumama u okolici Budimpešte. Posjetili su UŠP Vinkovce, UŠP Nova Gradiška i NP Plitvička jezera. Organizator posjeta bila je središnjica HŠD u suradnji s ograncima HŠD i podružnicama Hrvatskih šuma u Vinkovcima i Novoj Gradiški te članovima HŠD iz NP Plitvička jezera. (Oliver Vlainić)
- 14. – 15. lipnja 2025. – U Salinovcu održan 10. hrvatski festival kiparenja motornom pilom. HŠD je tradicionalno pomogao u organizaciji festivala plaćanjem dijela troškova , a Ogranak Varaždin je pomogao u postavljanju izložbe fotografija „Šuma okom šumara" u vrijeme trajanja festivala. Organizator festivala s lokalnom udrugom je prof. dr. sc. Krunoslav Lepoglavec s Fakulteta šumarstva i drvne tehnologije Sveučilišta u Zagrebu.
- 17. lipnja 2025. – Na Medvednici u organizaciji Hrvatskih šuma d.o.o. UŠP Zagreb održana je prezentacija za udruge i medije o sanaciji šuma Medvednice nakon

desetljeća olujnih nevremena. Grad Zagreb i Park prirode Medvednica sudjelovali u aktivnosti. (Ivan Krajačić)

- 17. lipnja 2025. – Otvorena izložba 20. Bjelovarskog salona fotografije „Šuma okom šumara" s međunarodnim sudjelovanjem u Bjelovaru. Izložene su samo nagrađene i pohvaljene fotografije zbog nedostatka adekvatnog prostora zbog obnove u gradskim prostorima. (Martina Pavičić)
- 17. – 19. lipnja 2025. – Na temelju suradnje s Njemačkim šumarskim društvom središnjica HŠD organizirala je trodnevno stručno usavršavanje za tri njemačka prvostupnika šumarstva pripravnika iz savezne države Meklenburg-Zapadna Pomeranija. Posjetili su Fakultet šumarstva i drvne tehnologije, Šumarski dom, šumarije Jastrebarsko i Zagreb. (Oliver Vlainić)
- Lipanj 2025. – Diljem Hrvatske održana međunarodno šumarska entomološka ekspedicija. Organizator ekspedicije bio je profesor Boris Hrašovec s Fakultet šumarstva i drvne tehnologije. U 11 dana od istoka Slavonije, preko Gorskog kotara, Like, do Paklenice, obale i otoka, eminentni znanstvenici iz Švedske, Norveške, Češke i Hrvatske, proučavali su bogatu entomofaunu hrvatskih šuma.
- 4. – 5. srpnja 2025. – U Bonnu u Njemačkoj održana godišnja skupština Europskog vijeća za arborikulturu (EAC) čiji je član Sekcija za urbano šumarstvo HŠD. Hrvatska udruga za arborikulturu je također u tom savezu. Kolega Goran Huljenić nije član HŠD pa ne može službeno predstavljati HŠD. (Damir Dramalija i Goran Gregurović)
- Srpanj 2025. – objavljen je brošura „Primjeri dobre prakse karijerne orijentacije u šumarstvu" koja je nastala u okviru projekta Fem2forests. U brošuri su objavljeni primjeri dobre prakse iz devet država. Za Hrvatsku je uvršten Dan otvorenih vrata Hrvatskoga šumarskog instituta te program informiranja i promocije šumarske struke u hrvatskim srednjim školama u provedbi Fakulteta šumarstva i drvne tehnologije. U sklopu međunarodnog projekta Fem2Forests na međunarodnom natječaju Graphic Novel, na kojem su sudjelovale učenice šumarskih škola iz osam europskih zemalja, pobijedio je rad hrvatske predstavnice Chiare Gašparac. (Silvija Zec)
- 9. kolovoza 2025. – Ekipa bjelovarskih lađara sudjelovala je na 28. Maratonu lađa na Neretvi i osvojila je 14. mjesto od 32 ekipe. (Martina Pavičić)
- 3. – 5. rujna 2025. – Dopredsjednica HŠD Mandica Dasović i tajnik HŠD Oliver Vlainić sudjelovali na 9. šumarijadi FBiH u Olovu u organizaciji JP Šumsko-privrednog društva Zeničko-dobojskog kantona. Više o šumarijadama opisano je u Šumarskom listu 9-10/2025. (Oliver Vlainić)
- 4. rujna 2025. – Stupio na snagu Pravilnik o izmjenama i dopunama Pravilnika o provedbi intervencije 73.06. „Modernizacija šumarskih tehnologija u pridobivanju drva, šumskouzgojnim radovima i proizvodnji ŠRM-a (šumskog reprodukcijskog materijala)" i intervencije 73.07. „Modernizacija tehnologija u predindustrijskoj preradi drva" iz Strateškog plana Zajedničke poljoprivredne politike Republike Hrvatske za razdoblje 2023. – 2027. (Narodne novine broj 117 od 3. rujna 2025)
- 9. – 12. rujna 2025. – Na poziv Slovačke šumarske komore predstavnici HKIŠDT sudjelovali su u Slovačkoj na konferenciji o bukovom potkornjaku. Na konferenciji je sudjelovalo šezdesetak kolega iz Mađarske, šezdesetak iz Slovačke i sedam iz Hrvatske. (Silvija Zec)
- 11. – 13. rujna 2025. – U Našicama su održani 25. Dani slavonske šume. Ove godine je bilo skromnije nego inače bez stručnih predavanja i izložbe fotografija „Šuma okom šumara". (Darko Mikičić)
- 19. rujna 2025. – Znanstveno vijeće za zaštitu prirode i okoliša HAZU, Znanstveno vijeće za poljoprivredu i šumarstvo HAZU te Sekcija za urbano šumarstvo HŠD organizirali su okrugli stol „Utjecaj invazivnih stranih biljaka na upravljanje urbanim zelenim površinama". Od svih dosadašnjih okruglih stolova ovaj je bio na najvišem nivou. Posjet je bio jako dobar i stigla je pohvala od strane HAZU. (Damir Dramalija)
- 20. – 21. rujna 2025. – Hrvatski predstavnici Denis Štimac i Goran Bukovac sudjelovali na pripremnom sastanku za EFNS 2026. godine u Italiji. Sastanak je održan u Forni Avoltri. (Oliver Vlainić)
- 23. rujna 2025. – U zagrebačkom hotelu Sheraton održana je konferencija „Pripreme za EUDR procedure". Europska komisija najavila odgodu EU uredbe o deforestaciji (EUDR) za još jednu godinu radi prilagodbe. Odgoda je izglasana 26. studenog 2025. Tvrtke dobivaju dodatnu godinu za usklađivanje s novim pravilima EU za sprječavanje krčenja šuma. Veliki operatori i trgovci morat će poštovati obveze iz ove uredbe od 30. prosinca 2026., a mikro i mala poduzeća od 30. lipnja 2027. (Oliver Vlainić)
- 29. rujna 2025. – Nakon protupotresne obnove ponovno je otvoren i stavljen u funkciju IV. paviljon Fakulteta šumarstva i drvne tehnologije. Projekt je financiran iz Fonda solidarnosti EU, NPOO-a i Državnog proračuna, a obuhvatio je potpunu rekonstrukciju, modernizaciju instalacija, energetsku obnovu i osiguranje pristupačnosti osobama s otežanom pokretljivošću.

- Rujan 2025. – objavljeni su prvi natječaji za provedbu intervencije 73.06. „Modernizacija šumarskih tehnologija u pridobivanju drva, šumskouzgojnim radovima i proizvodnji ŠRM-a (šumskog reprodukcijskog materijala)" te 73.07. „Modernizacija tehnologija u predindustrijskoj preradi drva iz Strateškog plana Zajedničke poljoprivredne politike Republike Hrvatske 2023. – 2027."
- 3. – 5. listopada 2025. – Na otoku Rabu održani 3. šumarsko-sportski susreti Alpe-Adria o čemu je opširnije napisano u Šumarskom listu 9-10/2025. (Oliver Vlainić)
- 9. listopada 2025. – U Pazinu Hrvatski šumarski institut obilježio je tri značajne obljetnice: 260 godina hrvatskog šumarstva, 80 godina Hrvatskoga šumarskog instituta i 15 godina djelovanja istraživačkog centra za općekorisne funkcije šuma „Josip Ressel" na današnjoj adresi. Skup s dobrom posjećenošću održan je u suradnji s UŠP Buzet. (Sanja Perić)
- 10. – 12. listopada 2025. – Članovi Hrvatskoga šumarskog društva u Federaciji BiH posjetili su područje Hrvatskih šuma d.o.o. UŠP Gospić i HŠD Ogranka Gospić o čemu je objavljena vijest na mrežnoj stranici HŠD. (Valentina Kulaš)
- 16. listopada 2025. – Hrvatska komora inženjera šumarstva i drvne tehnologije bila je četvrti domaćin predstavnicima šumarskih institucija. U neformalnom druženju opet su razmijenjena mišljenja i stavovi o trenutnoj situaciji u sektoru. Sljedeći sastanak bit će na Fakultetu šumarstva i drvne tehnologije.
- 16. i 17. listopada 2025. – U Vinkovcima održan 7. hrvatski znanstveno-stručni skup o urbanom šumarstvu pod nazivom „Izazovi urbanog šumarstva u prilagodbi na klimatske promjene". Zabilježena je najveća posjećenost dosadašnjih skupova sa 150 sudionika. UŠP Vinkovci i ostali domaćini zaslužuju sve pohvale. (Damir Dramalija)
- 19. – 22. listopada 2025. – U Švedskoj održan godišnji skup Europske šumarske mreže ovaj put bez hrvatskih predstavnika. Predsjednik Švedskog šumarskog društva bio je u posjetu Hrvatskoj tjedan dana prije toga. Ostvarena je i suradnja s estonskim šumarima uzajamnim posjetom. (Stjepan Mikac)
- 20. – 24. listopada 2025. –Na temelju suradnje s Njemačkim šumarskim društvom središnjica HŠD organizirala je petodnevno stručno usavršavanje za tri njemačka magistra inženjera šumarstva pripravnika iz savezne države Meklenburg-Zapadna Pomeranija. Posjetili su Fakultet šumarstva i drvne tehnologije, Šumarski dom, Nadbiskupske šume u Gračecu, šumarije Vojnić i Rab, nacionalne parkove Plitvička jezera i Risnjak. Kao i kod prve grupe zahvala Fakultetu na smještaju i svim kolegama na uredskim i terenskim prezentacijama. (Oliver Vlainić)
- 21. – 23. listopada 2025. – U Zagrebu je održan 4. sastanak partnera projekta Fem2forests. U sklopu sastanka hrvatski projektni partneri, Hrvatska komora inženjera šumarstva i drvne tehnologije i Hrvatski savez udruga privatnih šumovlasnika organizirali su i izlet na područje Medvednice. Fakultet šumarstva i drvne tehnologije te UŠP Zagreb doprinijeli su odličnoj organizaciji sastanka, koja je posebno oduševila učenice Srednje škole Delnice te Škole drvne tehnologije i šumarstva Zagreb, koje su sudjelovale u dijelu programa na poziv Komore. (Silvija Zec)
- 24. listopada 2025. – Fakultet šumarstva i drvne tehnologije Sveučilišta u Zagrebu svečano je obilježio 127. godišnjicu fakulteta.
- Listopad 2025. - Djelatnice Fakulteta šumarstva i drvne tehnologije zajedno s Hrvatskom komorom inženjera šumarstva i drvne tehnologije sudjelovale su na Islandu na međunarodnoj konferenciji „Growing Together: Women, Forests and a Sustainable Future", u sklopu projekta Fem2forest. (Silvija Zec)
- Listopad i studeni 2025. – Hrvatske šume raspisale natječaj za 30 stipendija, a Hrvatski savez udruga šumovlasnika i Udruga šumovlasnika za dvije stipendije studentima prijediplomskih i diplomskih studija na FŠDT. To je najviše ugovorenih stipendija do sada.
- 3. – 6. studeni 2025. – Fakultet šumarstva i drvne tehnologije obavio postupak reakreditacije u kojemu su sudjelovali predstavnici dionika koji surađuju s Fakultetom među kojima je bilo i HŠD.
- 6. studenog 2025. – Vlada RH predložila Skupštini društva Hrvatske šume d.o.o. imenovanje Joška Radanovića za predsjednika Uprave HŠ i Nediljka Dujića za člana Uprave HŠ do imenovanja predsjednika i člana Uprave putem javnog natječaja na razdoblje od najduže šest mjeseci. Primopredaja je obavljena 19. studenog 2025. Prvi put u povijesti nijedan šumar nije član Uprave Hrvatskih šuma!!!
- 8. studenog 2025. – Ogranak Vinkovci u suradnji s ostalim ograncima organizirao 14. biciklijadu Vinkovci/Osijek – Vukovar. Sudjelovalo je tridesetak sudionika. Pozivaju na još veći odaziv sljedeće godine. (Anto Glavaš)
- 12. studenoga 2025. – U Jastrebarskom Hrvatski šumarski institut obilježio 80 godina osnutka. Bila je velika posjećenost s promocijom monografije i prikazom trenutnih aktivnosti Instituta. (Sanja Perić)
- 13. – 14. studenog 2025. – U Jastrebarskom u organizaciji Hrvatskoga šumarskog instituta održana

međunarodna znanstvena konferencija mladih znanstvenika. Konferencija je bila interdisciplinarna jer su među 80 sudionika osim šumara sudjelovale i druge struke. (Sanja Perić)

- 15. studenog 2025. – Na više mjesta u Hrvatskoj u organizaciji ogranaka i sekcija obilježen je Dan urbanog šumarstva. Ogranci Karlovac i Virovitica bili su uključeni s edukativnom šetnjom i sadnjom sadnica. U sklopu mrežne stranice www.sumari.hr završena je podstranica Sekcije za urbano šumarstvo te je postala javna. (Damir Dramalija)
- 20. studenog 2025. – U prostoru Fakulteta šumarstva i drvne tehnologije na inicijativu predsjednice Hrvatske komore inženjera šumarstva i drvne tehnologije Silvije Zec održana je tematska sjednica Odbora za poljoprivredu Hrvatskog Sabora povodom 260 godina hrvatskog šumarstva. Prvi put u povijesti na Fakultetu je održana sjednica s nazočnošću saborskih zastupnika. (Silvija Zec)
- 21. studenog 2025. – U organizaciji Hrvatskih šuma d.o.o. UŠP Zagreb, Grada Zagreba i Hrvatskoga šumarskog društva – Sekcije za urbano šumarstvo otvorena je prva Poučna staza urbanog šumarstva Jelenovac. (Damir Dramalija)
- 21. studenog 2025. – Časopis „Drvo & namještaj" organizirao je u Novinarskom domu u Zagrebu stručnu konferenciju „Ugovori za drvnu sirovinu – budućnost opskrbe i razvoja drvne industrije" s ciljem analize dosadašnjih prodajnih modela ugovora za drvnu sirovinu te definiranje održivog modela **raspodjele** (?!) koji će osigurati konkurentnost i stabilnost sektora. HŠD se protivi takvom načinu netržišnih odnosa koji idu na štetu šumarstva. Hrvatske šume istaknule su kako je pitanje ugovora jedan od glavnih izazova koji će se rješavati u sljedećoj godini. (Silvija Zec)
- Hrvatski inženjerski savez počeo je s obnovom doma HIS na adresi Berislavićeva 6 u Zagrebu. Početkom lipnja 2025. godine obratili su se za pomoć HŠD radi održavanja sjednica Upravnog odbora HIS i skupština HIS u Šumarskom domu. Dosada je održano pet sjednica Upravnog odbora i dvije sjednice Skupštine HIS. Zbog smrti predsjednika HIS Zdravka Jurčeca 6. listopada 2025. HIS je 13. studenog 2025. održao izvanrednu sjednicu Skupštine i za novog predsjednika izabran je Luka Jelić, dipl. ing. građ., direktor Hidroprojekt-inga, član Predsjedništva Hrvatskog saveza građevinskih inženjera i član Društva građevinskih inženjera Zagreb. (Oliver Vlainić)
- Predsjednica Sekcije za povijest šumarstva Mandica Dasović iznijela je Izvješće o radu Sekcije za povijest šumarstva od 1. sjednice UO HŠD 23. svibnja 2025. do danas:
- Tijekom srpnja 2025. godine presloženi su ormari s knjigama u Velikoj dvorani Šumarskog doma. Preko dvije tisuće knjiga pregledano je i ponovno upisano radi točne lokacije smještaja u ormarima. Nakon posljednjeg krečenja prostora prizemlja Šumarskog doma knjige nisu vraćene u ormare prema prvotnom popisu te se nije znala njihova lokacija što je radilo poteškoće u pronalaženju prilikom raznih zahtjeva za korištenje ili skeniranje knjiga.
- Skenirano je pet knjiga, svi brojevi Šumarskih novina Šumskog gospodarstva „Josip Kozarac" Nova Gradiška (1974. – 1980.) te veći broj starih fotografija iz foto arhive HŠD.
- Jedno staro računalo je iskorišteno kao server za pohranu fotografija.
- Šumarija Rijeka darivala je kopije dijela svoje arhivske građe, a Vice Ivančević dvadesetak starih knjiga.
- Povodom obilježavanja 75 godina u 2026. godini pri kraju su tekstovi za knjigu o povijesti Ogranka Gospić i ličkog šumarstva te za knjigu o povijest Ogranka Nova Gradiška i novogradiškog šumarstva. U pripremi je i knjiga o povijesti 70 godina Ogranka Varaždin.

Ad 3. Aktualna problematika

a) *Šumarski dom*

Tajnik HŠD Oliver Vlainić iznio je aktualnu problematiku vezanu uz Šumarski dom.

Na portalu Ministarstva prostornog uređenja, graditeljstva i državne imovine *Pregled obnove privatnih nekretnina oštećenih u potresu – Statusi obnove objekata prema lokaciji* za status samoobnove Šumarskog doma **nema promjena** od prethodne sjednice u svibnju 2025. godine

Radovi u Šumarskom domu u razdoblju od protekle sjednice:

U listopadu 2025. godine obavljeni su radovi na uređenju ulaznih vrata i soboslikarski radovi u dijelu hodnika na Trgu Mažuranića 11 i Vukotinovićevoj 2. Dvoja vrata su nakon pripreme i zaštite oličena izvornom bojom. Neposredno uz vrata sanirani su oštećeni dijelovi zida od poda do stropa. Sanirani su i zidovi hodnika između uredskih prostora od ulaza do Velike dvorane koji su oštećeni u potresima 2020. godine. Napravljena je zaštita stolova u dvorani Šumarski četvrtak. Izvoditelj radova bila je tvrtka Lea-trgovina d.o.o. iz Zaprešića, a ukupni trošak s PDV iznosio je 4.889,90 eura.

Stanje sudskog spora s Fakultetom kemijskog inženjerstva i tehnologije

Obavijest odvjetničkog društva Kos&Partneri od 23. studenog 2025. o stanju sudskih sporova:

U predmetu koji se pred Trgovačkim sudom u Zagrebu vodi pod brojem P-793/24, po tužbi FKIT-a protiv HŠD-a, radi proglašenja ovrhe nedopuštenom, i dalje očekujemo sud da zakaže novu raspravu. Sud je dopisima tražio od Općinskog građanskog suda u Zagrebu dostavu predmeta poslovnog broja Ovr-1351/23 u rujnu i početkom studenog 2025. godine.

U predmetu ovrhe, Ovr-1351/23, nakon što je FINA obavijestila sud da je ovrha u potpunosti naplaćena, zatraženi su naknadni troškovi ovršnog postupka. Očekujemo donošenje dopunskog rješenja o naknadnim troškovima ovršnog postupka.

U predmetu P-1115/21, Općinski građanski sud u Zagrebu, nije bilo nikakvih novosti, osim što je predmet povodom žalbe dodijeljen u rad drugom sucu – i dalje očekujemo donošenje drugostupanjske odluke Županijskog suda u Zagrebu povodom žalbe.

b) *Spomen-obilježja akademiku Slavku Matiću i profesoru Branimiru Prpiću*

Tajnik Oliver Vlainić iznio je stanje s aktivnosti oko postavljanja spomen-obilježja:

25. lipnja 2025. Skupštini grada Zagreba poslan dopis s upitom za postavljanje spomen-ploča i potrebnih uvjeta. Nakon ponovljenog upita 27. listopada stigao odgovor iz grada 31. listopada 2025. Upućeni smo na dobivanje prethodnog odobrenja/stručnog mišljenja *Gradskog zavoda za zaštitu spomenika kulture i prirode*. Nakon toga uputiti zahtjev s idejnim projektom *Povjerenstvu za ploče za označavanje imena ulica i trgova, spomenike, skulpture, spomen-ploče, sakralna obilježja i umjetničke instalacije*. Trenutno se dogovara izrada idejnog projekta s ovlaštenim arhitektom.

Predsjednik Igor Anić obavio je razgovor s akademskim kiparom Nevenom Bilićem, profesorom na Akademiji likovnih umjetnosti Sveučilišta u Zagrebu, vezano za ponudu za izradu reljefa. Kipar neće davati ponudu dok se ne ishoduju uvjeti za postavljanje spomen-ploča.

c) *Fiskalizacija 2.0*

Voditeljica računovodstveno-financijskih poslova Biserka Marković upoznala je članove UO s početkom Fiskalizacije 2.0 od 1. siječnja 2026. Još ne postoje odgovori na sva pitanja u funkcioniranju poslovanja pogotovo zbog kompleksnosti HŠD s 19 ogranaka te profitnoj i neprofitnoj djelatnosti. Nabavit će se dopuna računovodstvenog programa Synesis s modulom za fiskalizaciju.

Obrazložila je potrebu donošenja Odluke o pravilima slijednosti numeričkih brojeva računa, o poslovnom prostoru, oznaci poslovnog prostora i operatera na naplatnom uređaju o prodajnom mjestu

Odluka o pravilima slijednosti numeričkih brojeva računa, o poslovnom prostoru, oznaci poslovnog prostora i operatera na naplatnom uređaju o prodajnom mjestu jednoglasno je usvojena.

d) *Cjenik oglašavanja u Šumarskom listu*

Budući da je iskazan interes za oglašavanje u Šumarskom listu treba donijeti cjenik.

Prijedlog odluke za cjenik:

Odluka o cjeniku oglašavanja u Šumarskom listu

Stavka	Cijena neto bez PDV	Cijena bruto s PDV	Valuta
1/1 stranica	384,00	480,00	EUR
1/2 stranice	192,00	240,00	EUR
1/3 stranice	128,00	160,00	EUR
1/4 stranice	96,00	120,00	EUR
1/8 stranice	48,00	60,00	EUR

Ova Odluka primjenjuje se od 1. siječnja 2026.

Odluka o cjeniku oglašavanja u Šumarskom listu jednoglasno je usvojena.

e) *Članstvo i članske iskaznice*

Radi legitimiteta 129. sjednice Skupštine HŠD potrebno je ažurirati stanje članstva s plaćenom članarinom koji će definirati broj delegata po ograncima.

Radi izrade članskih iskaznica za nove članove potrebno je ažurirati stanje članstva svih kategorija članova i izvanrednih i počasnih.

Rasprava o članarini:

Daniela Cetinjanin potaknula je na razmišljanje o povećanju iznosa članarine za ubuduće.

Dražen Mikičić naveo je primjer Ogranka Našice koji preko donacije članstva povećava prihode Ogranka.

Biserka Marković dodala je da tri ogranka imaju donaciju članova uz redovitu članarinu.

Dalibor Tonc iznio je novi model plaćanja članarine u Ogranku Osijek van obustava na plaći. Postavio je pitanje mogućnosti plaćanje preko računa s kodom?

Biserka Marković odgovorila je kako je moguće napraviti pojedinačne račune s kodom, ali to otvara pitanje stvaranja potraživanja.

Zaključeno je da se za sljedeću sjednicu predloži visina povećane članarine.

Ad 4. Rebalans financijskog plana HŠD za 2025. godinu

a) *Rebalans financijskog plana za 2025. godinu*

Rebalans financijskog plana HŠD za 2025. godinu prezentirala je voditeljica računovodstveno-financijskih poslova HŠD Biserka Marković:

I. Plan prihoda i rashoda

		PLAN EUR	REBALANS PLANA EUR
	PRIHODI		
31	Prihodi od pružanja usluga	8.000,00	8.840,00
32	Članarine	86.580,00	85.860,00
34	Prihodi od imovine	200.000,00	207.000,00
35	Prihodi od donacija	107.200,00	198.140,00
36	Ostali prihodi	48.700,00	56.160,00
	UKUPNO PRIHODI:	**450.480,00**	**556.000,00**
	RASHODI		
41	Rashodi za radnike	114.000,00	115.620,00
42	Materijalni rashodi	331.110,00	452.335,00
43	Amortizacija	1.000,00	2.400,00
44	Financijski rashodi	5.670,00	5.130,00
45	Donacije	0,00	
46	Ostali rashodi	1.100,00	4.095,00
	UKUPNO RASHODI:	**452.880,00**	**579.580,00**
52	**REZULTAT:**	**-2.400,00**	**-23.580,00**
	Preneseni višak prihoda iz ranijih razdoblja	488.534,63	488.534,63
	Manjak 31.12.2024.	-39.600,00	-39.600,00
	Manjak 31.12.2025.	-2.400,00	-23.580,00
	Višak za prijenos u buduće razdoblje	446.534,63	425.354,63

II. Obrazloženje rebalansa financijskog plana

Na temelju poznatih podataka o kretanju i stanju prihoda i rashoda na dan 31. 10. 2025. sa sigurnošću znamo da će doći do odstupanja kako u planiranim prihodima tako i u planiranim rashodima. Stoga postoji potreba za rebalansom plana koji je postavljen za 2025. godinu.

Procjena prihoda i rashoda je napravljena na temelju knjigovodstvenih podataka proknjiženih na dan 31. 10. 2025., te procjenjivih podatka o prihodima i rashodima koji su vezani za posljednja dva mjeseca poslovanja središnjice i ogranaka.

PRIHODI

U planu za 2025. godinu **ukupni prihodi** bili su predviđeni u ukupnom iznosu od 450.480,00 EUR, dok u predloženom rebalansu iznose 556.000,00 EUR. Povećanje koje je vidljivo u ostvarenju odnosi se najvećim dijelom na prihode od primljenih donacija.

Prvotnim planom predviđeni **prihodi od pružanja usluga**, koji se odnose na usluge sponzorstva na sportskim događanjima i na prigodnim manifestacijama, iznosili su 8.000,00 EUR, a prema novoj procjeni do kraja godine bit će ostvareni u ukupnom iznosu od 8.840,00 EUR.

U skladu s dosadašnjom evidencijom i dinamikom plaćanja članarina po ograncima u kategoriji **prihoda od članarina** predviđamo da će se ostvariti iznos od 85.860,00 EUR što je nešto manje od ranijim planom predviđenih 86.580,00 EUR.

Prihod od najamnine planirali smo u iznosu od 200.000,00 EUR. Očekuje se da ćemo godinu završiti iznosom od 207.000,00 EUR. Naime, uz iznose najamnine koji su poznati temeljem ugovora u ovoj kategoriji prikazuju se i varijabilni iznosi najamnine tj. iznosi prefakturiranih zajedničkih troškova najmoprimaca za potrošenu električnu energiju i vodu.

Najveća promjena u odnosu na planirane iznose je u **prihodima od donacija**. Planom je u ukupnom iznosu predviđeno 107.000,00 EUR, no evidentno je da će taj iznos biti premašen. Prema procjeni iznos ukupno primljenih donacija dosegnut će iznos od 198.140,00 EUR.

Prihodi od donacija, i to ***donacija iz državnog proračuna i tijela lokalne samouprave***, koji uobičajeno prate i pomažu rad ogranaka, veći su od planiranih. Prema podacima dobivenim iz ogranaka procjenjujemo da će ti prihodi biti 12.250,00 EUR, a planom je bilo predviđeno 7.300,00 EUR.

Dvostruko povećanje ostvareno je od ***donacija trgovačkih društava*** koji smo planirali s iznosom od 87.000,00 EUR, a prema ostvarenju u vrijeme izrade rebalansa, procjenjujemo da će biti ostvarene u iznosu od 167.140,00 EUR.

Za ***prihod od državne uprave*** koji se odnosi ***na potporu izdavanju Šumarskog lista*** nije moguće sa sigurnošću planirati da će biti ostvaren, ali smo u rebalansu ostavili ranije planirani iznos od 10.000,00 EUR s obzirom da je prošle godine rješenje o dodjeli potpore stiglo u prosincu.

Procjenjujemo da će ***prihodi od donacija građana – članova društva*** biti veći nego smo predvidjeli s 2.900,00 EUR, tako da su rebalansu navedeni u iznosu od 5.750,00 EUR.

U kategoriji **ostali prihodi** planiran je iznos od 48.700,00 EUR, a prema sadašnjoj procjeni ti će prihodi iznositi 56.160,00 EUR. Naime, u ovoj skupini glavni prihod koji ovdje evidentiramo je ***prihod od pretplate na Šumarski list*** i on bi trebao biti ostvaren u iznosu od 50.300,00 EUR, dok se preostali iznos od 3.560,00 EUR odnosi na ***prihode od potpore po Uredbi Vlade RH*** vezane za umanjenje obveze plaćanja troškova pod potrošnje struje i plina te izvanredne prihode u iznosu 2.300,00 EUR. ***Izvanredni prihodi*** rezultat su naknadno izdanih rješenja Gradskog komunalnog gospodarstva kojima su izmijenjeni iznosi komunalne naknade od 2023. do 2025. godine. Prema rješenju iz 2023. u toj poslovnoj godini ukalkulirani su troškovi za koje nisu bili izdani računi već samo rješenje. U veljači 2025. po primitku

novog rješenja za 2023. ispostavilo se da su ti troškovi znatno manji te se u 2025. godini iskazuju kao izvanredni prihodi.

RASHODI

U planu za 2025. godinu **ukupni rashodi** predviđeni su u iznosu od 452.880,00 EUR, dok u predloženom rebalansu iznose 579.580,00 EUR.

Na ukupno povećanje rashoda kao i na najveće odstupanje u odnosu na plan, postavljen u prosincu prethodne godine, utjecale su tri kategorije rashoda – troškovi reprezentacije, troškovi stručnih ekskurzija i troškovi intelektualnih usluga koji su bitno veći od planiranih.

Što se tiče troškova reprezentacije i troškova stručnih ekskurzija ovu situaciju moguće je očekivati, ali ne i predvidjeti visinu ostvarenih iznosa. Te dvije kategorije troškova su u direktnoj ovisnosti o realiziranim donacijama. Kao što se vidi iz proknjiženih podataka donacije su ostvarene u značajno većem iznosu nego je bilo očekivano u vrijeme izrade plana. Kako su ostvarene donacije namijenjene pomaganju aktivnosti društva, tako su aktivnosti i manifestacije realizirane u većem obimu, što ima za posljedicu povećanje rashoda u gore navedenim kategorijama.

Planom za 2025. godinu predviđeni su **troškovi reprezentacije** u iznosu od 95.400,00 EUR, a za očekivati je da će na kraju ove poslovne godine oni iznositi 136.950,00 EUR. Za **stručna putovanja** predvidjeli smo 63.200,00 EUR, međutim prema knjigovodstvenom stanju 31. 10. te podacima ogranaka o realiziranim troškovima oni će iznositi do 104.725,00 EUR. Kod **troškova intelektualnih usluga** predvidjeli smo iznos 45.300,00 EUR, a za očekivati je da će oni doseći iznos od 80.500,00 koliko predlažemo u rebalansu plana.

Ovdje je svakako potrebno detaljnije obrazložiti ovako veliko odstupanje od plana i kroz nekoliko prošlih godina uobičajene iznose troškova intelektualnih usluga. U ovoj kategoriji do sada su uglavnom bili obuhvaćeni rashodi autorskih honorara vezanih za izdavanje Šumarskog lista. Dakle, troškovi autorskih honorara uredništva, autora članaka objavljenih u Šumarskom listu te autorski honorari recenzenata. Ovi rashodi planiraju se u iznosu od 30.650,00 EUR. Ove godine u strukturi s iznosom od 23.500,00 EUR sudjeluju autorski honorari izvođača umjetničkih programa vezani uz aktivnosti ogranaka Vinkovci, Zagreb i Nova Gradiška. Treća velika stavka rashoda je iznos 21.200,00 EUR koji nismo očekivali u ovoj poslovnoj godini. Naime, od odvjetničke kuće Kos dobili smo obračun naknade koja im pripada po ugovoru o zastupanju u sporu s Fakultetom kemijskog inženjerstva i tehnologije pa nam tako ta kategorija uz njihovu mjesečnu naknadu iznosi ukupno 23.600,00 EUR. Ovdje su uključeni i rashodi za usluge učeničkog servisa od 1.500,00 EUR za poslove vezane uz izradu kataloga knjižnice HŠD kao i rashodi za redovni revizorski uvid u iznosu od 1.250,00 EUR.

U kategoriji **rashoda za radnike** nema značajnijih odstupanja.

U skupini **materijalnih troškova** predviđamo da će nekoliko kategorija odstupati od planiranog iznosa.

Tako, ***usluge za tekuće i investicijsko održavanje*** planirane su u iznosu od 3.200,00 EUR no zbog odluke da se saniraju posljedice potresa u hodniku prostora HŠD i obnovi boja na ulaznim vratima u zgradi Šumarskog doma sa strane Trga Mažuranića i iz Vukotinovićeve ulice ti rashodi su u rebalansu plana predviđeni u iznosu od 7.300,00 EUR. ***Troškovi zakupnina*** planirani su u iznosu od 8.300,00 EUR, a po procjeni biti će ostvareni u većem iznosu od 9.850,00 EUR, što je, uz najam računalnog programa za grafičku pripremu Šumarskog lista, posljedica višekratnog najma prostora za održavanje raznih skupova u ograncima.

Rashodi za grafičke usluge za Šumarski list su nešto niže od planiranog iznosa od 24.500,00 EUR i predviđamo da će iznositi 21.250,00 zbog izostanka troškova za grafičku pripremu za posljednja dva dvobroja. Jednako tako predviđamo da će ***rashodi za ostale grafičke usluge*** biti manje od planiranog iznosa od 5.650,00 EUR te ih u rebalansu predviđamo u iznosu od 3.760,00 EUR.

U kategoriji ***rashoda za telefon i poštu***, tj. poštanskih troškova za distribuciju Šumarskog lista, predviđamo manje odstupanje pa ih iskazujemo u iznosu od 8.000,00 EUR umjesto ranije planiranih 8.800,00 EUR.

Troškovi koji čine grupu materijalnih troškova – ***ostale usluge*** planirane su u iznosu od 3.800,00 EUR, no predviđamo da neće preći iznos od 1.500,00 EUR.

Troškove bankarskih usluga planirali u iznosu od 5.670,00 EUR, a prema kretanjima u prvih 10 mjeseci procijenili smo da će oni iznositi 5.130,00 EUR.

Ostali nespomenuti troškovi predviđaju se u iznosima koji bitno ne odstupaju od ranije planiranih i ne utječu na visinu ukupno planiranih troškova.

REZULTAT

Iz obrazloženih stavki prihoda i rashoda proizlazi **rezultat**, manjak u iznosu od 23.580,00 EUR, što je značajno odstupanje u odnosu na ranije planirani iznos manjka od 2.400,00 EUR koji je predviđen planom postavljenim krajem prošle godine.

Rebalans financijskog plana za 2025. godinu jednoglasno je usvojen.

b) *Samoprocjena za 2025. godinu*

Samoprocjenu za 2025. godinu prezentirala je voditeljica računovodstveno-financijskih poslova HŠD Biserka Marković:

Samoprocjena, tj. upitnik o funkcioniranju sustava financijskog upravljanja i kontrola za 2025. godinu, koji je obavezan prema Zakonu o financijskom poslovanju, poslan je članovima Upravnog odbora prije sjednice. Na dostavljenu samoprocjenu nije bilo primjedbi.

Samoprocjena za 2025. godinu jednoglasno je usvojena.

c) *Imenovanje Povjerenstva za popis imovine i potraživanja na dan 31. 12. 2025.*

Predloženo je Povjerenstvo za popis imovine i potraživanja HŠD na dan 31. 12. 2025. u sastavu:

Mr. sc. Damir Delač, dipl. ing. šum. – predsjednik
Igor Tijardović, dipl. ing. šum. – član
Ana Žnidarec – članica
Dorica Matešić, dipl. ing. šum. – zamjenica člana.

Povjerenstvo za popis imovine i potraživanja na dan 31. 12. 2025. jednoglasno je izabrano.

Ad 5. *Šumarski list* i ostale publikacije

Glavna urednica Šumarskog lista prof. dr. sc. Marilena Idžojtić podnijela je izvješće o Šumarskom listu od broja 7-8/2025 kada je preuzela mjesto glavne i odgovorne urednice časopisa:

1. 29. 5. 2025. održana je prezentacija časopisa Šumarski list na Fakultetu šumarstva i drvne tehnologije Sveučilišta u Zagrebu, a 8. 9. 2025. na Hrvatskom šumarskom institutu. Prezentacije su bile namijenjene znanstvenicima kao podsjetnik na tradiciju koju Šumarski list baštini, njegove vrijednosti za našu struku i indeksiranost u najvažnijim svjetskim bazama. Također su naglašene prednosti i mogućnosti koje časopis nudi za objavljivanje, ali i recenziranje članaka.

2. Od broja 7-8/2025:

Donesene su nove Upute za autore.

Definirano je da se članci objavljuju iz područja šumarstva, urbanog šumarstva i zaštite prirode, s geografskim naglaskom na Europu i Mediteran.

Članci se objavljuju na engleskom jeziku ili na hrvatskom jeziku uz prošireni sažetak, ključne riječi, naslov i opis priloga na engleskom jeziku.

3. Od broja 9-10/2025:

Nova rubrika „Iznimna stabla naših šuma", u kojoj želimo predstaviti pojedinačna stabla u našim šumama koja se ističu visinom, promjerom debla, volumenom, dobi, habitusom, kvalitetom debla, rijetkom pojavom, posebnim nalazištem ili nekim drugim posebnim obilježjem. Čitatelji su pozvani da se uključe u kreiranje ove rubrike i pošalju fotografije i detaljan opis takvih stabala. U broju 9-10 predstavljen je hrast lužnjak u prašumi Prašnik; autori su akademik Igor Anić (idejni začetnik rubrike), prof. dr. sc. Vinko Paulić i dr. sc. Domagoj Trlin. U broju 11-12 bit će predstavljena „Jela Car" iz Begovače u Lici; autorice su mr. sp. Mandica Dasović i Antonija Jurković Tomac.

4. U listopadu ove godine u Vinkovcima je održan 7. hrvatski znanstveno-stručni skup o urbanom šumarstvu. Sedam prezentacija ocijenjeno je zanimljivim za objavljivanje u obliku članaka te su autori pozvani da napišu članke za Šumarski list.

5. Do podnošenja ovoga Izvješća u online i tiskanom obliku zadnji je objavljen broj 9-10, a za broj 11-12 objavljena je verzija *online first* (znanstveni, pregledni i stručni radovi na web-u), dok će cjelovita tiskana verzija biti objavljena u prosincu. Najveći izazov je nedostatak kvalitetnih znanstvenih, preglednih i stručnih radova, uz značajan broj odbijenih radova. Člancima su popunjeni brojevi 1-2 i 3-4, a popunjavamo broj 5-6/2026.

6. Od broja 1-2/2026:

Planirana je promjena izgleda časopisa.

Planirano je proširenje Uredničkog odbora. Prijedlog je da članovi Uredničkog odbora iz Hrvatske u časopisu budu navedeni abecednim redoslijedom prezimena, uz navođenje institucije u kojoj rade, bez navođenja znanstveno-stručnih područja. Većina članova iz Hrvatske i do sada su bili članovi Uredničkog odbora. Također, članovi Uredničkog odbora iz inozemstva bili bi posebno navedeni, prema abecednom redoslijedu prezimena, uz navođenje institucije u kojoj rade. Planirano je uspostavljanje Savjetodavnog odbora, čiji bi članovi bili umirovljenici. Popisi predloženih članova Uredničkog i Savjetodavnog odbora nalaze se u prilogu ovom Zapisniku a biti će otisnuti u sljedećem broju časopisa.

Svi predloženi članovi Uredničkog odbora iz Hrvatske i iz inozemstva te članovi Savjetodavnog odbora časopisa Šumarski list jednoglasno su izabrani.

Redizajn Šumarskog lista

Tehnički urednik Branko Meštrić od broja 7-8/2025 radi i grafičku pripremu Šumarskog lista. Budući da je sadašnji format i izgled časopisa isti od 1994. godine, a grafički dizajn, u izradi tvrtke Laser Plusa, od 2012. godine Branko Meštrić predložio je potrebu redizajna časopisa. Kao uzor za redizajn uzeo je francuski šumarski časopis. Nakon prezentacije izgleda redizajniranih stranica i naslovnice u raspravi je podržan redizajn s određenim doradama. Zaključeno je da će tehnički urednik Branko Meštrić izraditi tri prijedloga naslovnice Šumarskog lista. Elektroničkim glasanjem članova Upravnog odbora odabrat će se nova naslovnica Šumarskog lista od broja 1-2/2026.

Dopuna cijena autorskih honorara za Šumarski list

Prelaskom na vlastitu grafičku pripremu Šumarskog lista s unajmljenom aplikacijom *Adobe Creative Cloud* potrebno je dopuniti Odluku o visini autorskih honorara

za Šumarski list za cijenu **grafičke pripreme** i **korekture** Šumarskog lista. Prijedlog cijena je sljedeći:

Odluka o visini autorskih honorara za Šumarski list (u neto iznosima):

Stavka	Jedinica	Cijena po jedinici	Valuta
Redakcijsko djelo glavnog urednika	otisnuta stranica s tekstom i slikama	8,00	EUR
Redakcijsko djelo tehničkog urednika	otisnuta stranica s tekstom i slikama	6,00	EUR
Grafička priprema	**otisnuta stranica s tekstom i slikama**	**6,00**	**EUR**
Lektura	kartica teksta od 1800 znakova s razmacima	4,00	EUR
Prevođenje	kartica teksta od 1800 znakova s razmacima	13,00	EUR
Korektura	**otisnuta stranica s tekstom i slikama**	**1,00**	**EUR**
Stručni i ostali članci	otisnuta stranica s tekstom i slikama	25,00	EUR
Recenzija znanstvenog članka	članak	70,00	EUR
Recenzija stručnog članka	članak	30,00	EUR
Stručni prilog na zadnjoj stranici	otisnuta stranica s tekstom i slikama	100,00	EUR

Ova Odluka primjenjuje se od Šumarskog lista broj 7-8 /2025.

Odluka o visini autorskih honorara za grafičku pripremu i korekturu Šumarskog lista jednoglasno je usvojena.

Ad 6. Pripreme za 129. redovitu sjednicu Skupštine HŠD

129. redovita sjednica Skupštine HŠD održat će se 11. prosinca 2025. s početkom u 11 sati u prostorijama Knjižnice Hrvatske akademije znanosti i umjetnosti, Strossmayerov trg 14, Zagreb. Prvi put u povijesti sjednica Skupštine HŠD održat će se u prostorima HAZU.

Dnevni red sjednice Skupštine:

1. Izbor radnih tijela Skupštine:
   a) Radnog predsjedništva (predsjednika i 2 člana)
   b) Zapisničara
   c) Ovjerovitelja zapisnika (2 člana)
2. Izvješće o radu HŠD od prethodne Skupštine:
   a) Izvješće Predsjednika HŠD
   b) Izvješće Glavnog urednika Šumarskog lista
3. Rebalans financijskog plana HŠD za 2025. godinu
4. Program rada i financijski plan HŠD za 2026. godinu
5. Slobodna riječ.

Dnevni red 129. redovite sjednice Skupštine HŠD jednoglasno je usvojen.

U pozivu će se naznačiti da svi koji imaju šumarska odijela dođu u njima na sjednicu Skupštine radi zajedničkog fotografiranja.

Ad 7. Program rada i financijski plan HŠD za 2026. godinu

a) ***Program rada HŠD za 2026. godinu***

- Okupljati šumarsku struku i znanost te aktivno sudjelovati u svim aktivnostima vezanim za šumarsku tematiku.
- Ukazivati na potrebu odnosa prema šumi kao složenom ekosustavu, a ne kao izvoru drvne sirovine, posebice u uvjetima izraženih posljedica klimatskih promjena, čestih prirodnih nepogoda, pojave novih i gradacije dosadašnjih štetnika i bolesti.
- Poticati institucije koje izravno ili neizravno imaju utjecaj na gospodarenje šumama da se s obzirom na nove okolnosti, koristeći svoje znanje, iskustvo i znanstvena dostignuća, zajedničkim snagama odupru opasnostima koje prijete opstanku naših šuma.
- Braniti šumarstvo i šume prilikom neargumentiranih napada pojedinaca, udruga i institucija koji su posljedica neznanja i interesa suprotnih postulatima struke.
- Poticati i sudjelovati u edukaciji građana svih dobi o gospodarenju šumama koje se temelji na zagrebačkoj školi uzgajanja šuma.
- Poticaj razvoj i primjenu šumske pedagogije.
- U okviru mogućnosti i u suradnji s drugim šumarskim institucijama nastojati poboljšati status zaposlenika u hrvatskom šumarstvu čime bi se djelovalo na zaustavljanje trenda smanjenog interesa mladih ljudi za šumarskim obrazovanjem.
- Nastaviti aktivnosti u cilju privlačenja i pomlađivanja članstva HŠD.
- Podržati aktivnosti ogranaka HŠD na promicanju šumarske struke kroz izdavaštvo, organizaciju stručnih skupova, radionica, okruglih stolova, druženja i stručnih ekskurzija, podizanje spomen-obilježja zaslužnim šumarima i slično.
- Pružiti logističku podršku sekcijama HŠD da u skladu s idejom osnivanja okupljaju specijaliste iz svojih područja i aktivno sudjeluju u svim događanjima vezanim za svoja područja kao i u organizaciji domaćih i međunarodnih skupova.
- Obilježiti prigodnim aktivnostima Rođendan hrvatskog šumarstva 23. veljače, Međunarodni dana šuma 21. ožujka, Dan planeta Zemlje 22. travnja, Dan hrvatskog šumarstva 20. lipnja i Dan urbanog šumarstva 15. studenoga.

- Tijekom godine s više aktivnosti obilježiti 180 godina rada Hrvatskoga šumarskog društva i 150 godina neprekinutog izlaženja znanstveno-stručnog i strukovnog glasila Šumarski list.
- Spomen-obilježjima na zgradi Šumarskog doma iskazati počast akademiku Slavku Matiću i prof. emer. Branimiru Prpiću.
- Obilježiti 170 godina od rođenja profesora šumarstva Frana Žavera Kesterčaneka.
- Nastaviti podržavati uobičajene domaće i međunarodne sportsko-stručne i kulturne manifestacije sukladno njihovom održavanju: EFNS, Alpe-Adria, Međunarodni salon fotografija „Šuma okom šumara", maratone lađa, biciklijade i slično.
- Surađivati s Hrvatskom komorom inženjera šumarstva i drvne tehnologije (HKIŠDT) u održavanju stručnih predavanja i pripremi stručnih događanja s aktualnom šumarskom problematikom.
- Podržavati aktivnosti Akademije šumarskih znanosti.
- Promovirati šume i šumarstvo u aktivvnostima Hrvatske akademije znanosti i umjetnosti kroz Znanstveno vijeće za poljoprivredu i šumarstvo, Znanstveno vijeće za zaštitu prirode i okoliša te Centar za znanstveni rad u Vinkovcima.
- Sudjelovati u aktivnostima Hrvatskoga inženjerskog saveza (HIS).
- Uključiti se samostalno i u suradnji s drugima u izradu i provedbu raznih projekata od interesa za HŠD i šumarstvo.
- Održavati međunarodnu suradnju sa šumarskim društvima i šumarskim institucijama drugih zemalja.
- Redizajnirati Šumarski list u njegovoj 150 godini izlaženja.
- Motivirati domaće autore na objavljivanje u Šumarskom listu.
- Održati redovite sjednice Upravnog i Nadzornog odbora uobičajenim načinom, a po potrebi organizirati tematske sjednice.
- Održati redovitu sjednicu Skupštine HŠD, a po potrebi organizirati elektroničke sjednice.
- Nastaviti dopunjavati i ažurirati mrežnu stranicu www.sumari.hr.
- Pomagati ograncima i sekcijama u medijskoj vidljivosti na vlastitoj mrežnoj stranici i društvenim mrežama.
- Nastaviti projekt potpune digitalizacije knjižnice HŠD.
- Redovito održavati Šumarski dom i osmisliti namjenu neiskorištenog prostora potkrovlja.

Program rada za 2026. godinu jednoglasno je usvojen.

b) *Financijski plan HŠD za 2026. godinu*

Financijski plan HŠD za 2026. godinu prezentirala je voditeljica računovodstveno-financijskih poslova HŠD Biserka Marković:

I. Plan prihoda i rashoda

		PLAN EUR
	PRIHODI	
31	Prihodi od pružanja usluga	7.000,00
32	Članarine	85.860,00
34	Prihodi od imovine	207.000,00
35	Prihodi od donacija	102.440,00
36	Ostali prihodi	51.800,00
	UKUPNO PRIHODI:	**454.100,00**
	RASHODI	
41	Rashodi za radnike	115.100,00
42	Materijalni rashodi	334.950,00
43	Amortizacija	2.400,00
44	Financijski rashodi	5.800,00
45	Donacije	0,00
46	Ostali rashodi	2.500,00
	UKUPNO RASHODI:	**460.750,00**
52	**REZULTAT:**	**-6.650,00**
	Preneseni višak prihoda iz ranijih razdoblja	479.798,47
	Manjak 31.12.2025.	23.580,00
	Manjak 31.12.2026.	6.650,00
	Višak za prijenos u buduće razdoblje	449.568,47

II. Plan zaduživanja i otplata

U 2026. godini ne planiraju se zaduživanja, a budući da nema ni ranijih zaduživanja nema potrebe za planom otplate.

III. Obrazloženje financijskog plana

Financijski plan HŠD objedinjuje financijske planove 19 ogranaka i središnjice HŠD-a, i to njene neprofitne i profitne gospodarske djelatnosti.

PRIHODI

Ukupno planom predviđeni prihodi iznose **454.100,00 EUR**.

PRIHODI OD USLUGA

Prihodi od usluga planirani su u iznosu od **7.000,00 EUR**, a odnose se na prihode koji se ostvaruju na temelju ugovora o sponzorstvu. Kako se kroz prethodne godine pokazalo ova vrsta prihoda se redovito pojavljuje, a vezana je na već tradicionalna sportska događanja i manifestacije u organizaciji ogranaka i sekcija HŠD.

PRIHODI OD ČLANARINA

Prihodi od članarina u iznosu **85.860,00 EUR** procijenjeni su na temelju broja redovitih članova u 2025. godini i jedinstvene godišnje članarine koja iznosi 36,00 EUR.

PRIHODI OD IMOVINE

Prihodi od imovine su prihodi od iznajmljivanja poslovnog prostora, a planirani su u ukupnom iznosu od **207.000,00 EUR**. Planirani su na temelju poznate ugovorene najamnine s postojećim najmoprimcem IRMO koja na godišnjoj razini iznosi 66.361,40 EUR te najmoprimcem Stomatološkom poliklinikom koja za godinu iznosi 131.395,58 EUR, što je ukupno 197.756,98 EUR. Razlika do ukupno planiranog iznosa odnosi se na varijabilni dio prihoda od najma koji čine prefakturirani zajednički troškovi električne energije i vode, zatim prihodi od subvencija po odluci Vlade RH te prihodi od iznajmljivanja dvorana za sastanke koji se uobičajeno ostvare tijekom godine.

PRIHODI OD DONACIJA

U 2026. godini HŠD će nastaviti s izdavanjem znanstvenog časopisa Šumarski list. Kao i niz godina do sada HŠD će se prijaviti na natječaj kod Ministarstva znanosti, obrazovanja i mladih za potporu za izdavanje znanstvenog časopisa, a plan se temelji na iznosima dodjeljenim na natječajima ranijih godina. Prema dodijeljenim potporama u posljednjim godinama planirani iznos je 10.000,00 EUR.

Donacije od trgovačkih društava uobičajena su potpora radu HŠD i ostvarenju planiranih aktivnosti kroz dugi niz godina. Procjena je napravljena po ograncima, uz predviđanje interesa i mogućnosti trgovačkih društava te prema ostvarenjima prihoda po toj osnovi iz prethodnih razdoblja te na odazivu u 2025. godini. Kako su u 2025. godini ove donacije ostvarene u neočekivano visokom iznosu ne očekujemo da ćemo u 2026. godini doseći taj iznos već smo planom predvidjeli iznos od 80.000,00 EUR što nam izgleda realnije.

Tome smo pribrojili donacije iz proračuna lokalne samouprave od 8.000,00 EUR te građana i članova društva od 4.440,00 EUR, pa je ukupan planirani iznos prihoda od donacija iz svih izvora **102.440,00 EUR**.

OSTALI PRIHODI

U ostalim prihodima planirani su prihodi od pretplate na časopis Šumarski list. Procjena se temelji na poznatom broju pretplatnika i cijeni godišnje pretplate za jedan primjerak Šumarskog lista. Pretpostavka je da se neće promijeniti ugovorni odnos s nositeljem pretplate za 1.205 pretplatnika, Hrvatske komore inženjera šumarstva i drvne tehnologije, te da će Hrvatske šume nastaviti pretplatu za 200 pretplatnika. Promjena broja pojedinačnih pretplata nije od velikog utjecaja. Uobičajene su i pojedinačne pretplate, pa uključujući i njih planirani iznos je 50.300,00 EUR.

Među ostalim prihodima uračunati su i prihodi od subvencija po odluci Vlade RH koji su predviđeni u dvostruko manjem iznosu nego što su ostvareni tijekom 2025. godine s obzirom na najavu da će potpore ukinuti u prvoj polovini godine.

Ukupno planirani ostali prihodi iznose **51.800,00 EUR**.

RASHODI

Ukupno planom predviđeni rashodi iznose **460.750,00 EUR**.

RASHODI ZA RADNIKE

Rashodi za radnike planirani su na razini 2025. godine u ukupnom iznosu od **115.000,00 EUR**.

MATERIJALNI RASHODI

Materijalni rashodi planiraju se u ukupnom iznosu od **334.950,00 EUR.** Kako čine vrijednosno najznačajniju skupinu rashoda obrazlažemo ih po grupama.

Rashodi za službena putovanja, prijevoz i usavršavanje radnika: 2.900,00 EUR.

- planirani su prema ostvarenim rashodima iz prethodnog razdoblja, a objedinjuju troškove službenih putovanja radnika, naknadu za prijevoz te kotizacije za usavršavanje radnika.

Rashodi za naknade troškova osobama izvan radnog odnosa: 4.700,00 EUR.

- planirani su za pokriće troškova službenih putovanja osoba koje nisu zaposlene u HŠD već obavljaju funkcije na koje su izabrani. Procjena je napravljena uzimajući u obzir broj sjednica Upravnog odbora kojima trebaju prisustvovati njegovi članovi te naknadu za korištenje vlastitog vozila za obavljanje redovitih poslova te službena putovanja na tematske skupove vezane uz rad HŠD temeljem plana rada i aktivnosti za 2026. godinu. Ovdje su uključeni i troškovi službenih putovanja vezanih uz rad sekcija na skupove u inozemstvu.

Rashodi za usluge: 143.565,00 EUR.

- troškovi pošte i telefona 8.500,00 EUR – na razini troškova prethodne godine uz pretpostavku da se neće mijenjati troškovi distribucije Šumarskog lista poštom.

- troškovi tekućeg i investicijskog održavanja 3.800,00 EUR – u prostorijama koje koristi HŠD planira se izvršiti djelomična sanacija oštećenja od potresa u uredskim prostorijama i dvoranama.

Izvori za financiranje planiranih radova su prihodi od najamnine iz tekućeg razdoblja.

- komunalne usluge 6.500,00 EUR – planirani iznos je na razini prethodne godine.

- troškovi promidžbe 23.300,00 EUR – prema iskustvima ranijih godina i planiranim aktivnostima. U troškovima su predviđeni promotivni materijali i sitna galanterija s logom HŠD.

- troškovi zakupnina 5.100,00 EUR – prema iskustvima ranijih godina i planiranim aktivnostima.

- računalne usluge 200,00 EUR – procjena vrijednosti potrebnih intervencija u postojećem programu.

- intelektualne usluge – grupa rashoda planirana je prema prethodnim razdobljima u iznosu od 52.000,00 EUR. Odnose se na autorske honorare vezane uz izdavanje Šumarskog lista – honorari uredništva, autora objavljenih članaka i recenzija. Ove godine u ovu kategoriju uključeni su i troškovi grafičke pripreme Šumarskog lista s obzirom da pripremu više ne radi naš dugogodišnji partner firma Laser Plus već će je, uz korištenje programa koji je u najmu za tu svrhu, raditi tehnički urednik. Trošak autorskih honorara planira se u iznosu od 35.000,00 EUR. Preostali iznos u kategoriji intelektualnih usluga planiran je za honorare za umjetničke nastupe na manifestacijama i godišnjim skupštinama tijekom godine.

- grafičke usluge vezane za izdavanje Šumarskog lista planirane su u iznosu od 20.000,00 EUR.

- ostale grafičke usluge 5.600,00 EUR.

- ostale usluge 1.500,00 EUR.

Rashodi za materijal i energiju: 17.200,00 EUR

Troškovi su planirani prema ostvarenim rashodima prethodnoga razdoblja pod pretpostavkom da neće doći do povećanja cijene energenata.

Ostali nespomenuti rashodi ukupno: 182.450,00 EUR

- premije osiguranja 5.200,00 EUR

- članarine 2.400,00 EUR

- reprezentacija 86.000,00 EUR

- stručna putovanja 79.900,00 EUR

- ostali rashodi 8.950,00 EUR

Premija osiguranja planirana je prema prošlogodišnjim iznosima polica osiguranja imovine i vozila.

Članarina (Pro Silva, EAC) planirana je prema ostvarenim rashodima prethodnih razdoblja.

Rashodi za reprezentaciju obuhvaćaju troškove održavanja godišnjih skupština, sjednica, stručnih skupova, okruglih stolova i predavanja na razini ogranaka te na razini HŠD kao cjeline, zatim održavanja izložbe „Šuma okom šumara" te kataloga izložbe i drugih tematskih izložbi.

Rashodi za stručna putovanja procijenjeni su prema planu aktivnosti ogranaka i središnjice.

Rashodi za reprezentaciju i stručna putovanja u direktnoj su ovisnosti o prikupljenim donacijama na nivou ogranaka s obzirom da su članarine kao izvor financiranja ograničene brojem redovitog članstva.

AMORTIZACIJA

Amortizacija je planirana prema stvarnim obračunima amortizacije iz tekućeg razdoblja u iznosu od **2.040,00 EUR.**

FINANCIJSKI RASHODI

Financijski rashodi odnose se isključivo na usluge banke i platnog prometa, a planirani su na razini prethodne poslovne godine u kojoj je došlo do značajnog porasta cijene bankovnih usluga. Planirani iznos je **5.800,00 EUR.**

OSTALI RASHODI

U ovoj grupi su planom predviđeni rashodi u iznosu od **2.500,00 EUR** jer se po iskustvu ranijih godina naknadno utvrde rashodi iz ranijeg razdoblja te troškovi koji se po svojoj vrsti ne mogu rasporediti u gore prikazane grupe rashoda.

REZULTAT

Planirani rezultat iskazuje se kao **manjak prihoda** u odnosu na rashode i to u iznosu **6.650,00 EUR**.

Financijski plan za 2026. godinu jednoglasno je usvojen.

Ad 8. Pripreme za obilježavanje 180 godina HŠD i 150 godina Šumarskog lista

a) *Prijedlog programa obilježavanja*

Središnje svečano obilježavanje bit će u Zagrebu, a točna lokacija naknadno će se odrediti kao i mjesec obilježavanja.

Organizirat će se skup posvećen aktualnom trenutku u struci i projekcijama za budućnost.

Svi ogranci i sekcije neka s barem jednom aktivnošću obilježe ove velike obljetnice.

U svim aktivnostima tijekom godine treba naglašavati obljetnice i njihovu vrijednost.

Osigurati medijsku vidljivost obilježavanja u elektroničkim i tiskanim medijima te na portalima i društvenim mrežama.

Prikupljeno je više prijedloga logotipa objedinjenih za obje obljetnice od kojih su u uži izbor odabrana tri prijedloga. Elektroničkim glasanjem članova Upravnog odbora izabrat će se prijedlog koji će se koristiti tijekom godine.

b) *Priznanja zaslužnim pojedincima i institucijama*

Uobičajeno je od 150. obljetnice HŠD svakih 10 godina dodijeliti priznanja zaslužnim pojedincima i institucijama. Posljednji put priznanja su dodjeljena prilikom obilježavanja 170 godina HŠD.

Svaki ogranak do sljedeće sjednice Upravnog odbora neka predloži dva kandidata za priznanje. Središnjica i sekcije predložiti će nekoliko insitucija i pojedinaca,

ukupno desetak kandidata. Tako bi se ukupno dodijelilo oko pedesetak priznanja kao i prije 10 godina.

c) *Reprint Spomenice Šumarskog doma iz 1899. godine s dopunom*

Radi se na pripremi reprinta Spomenice, a izdat će se tijekom 2026. godine.

Ad 9. Pitanja i prijedlozi

- Predsjednik Akademije šumarskih znanosti prof. dr. sc. Marijan Grubešić upozorio je na slabu pozitivnu medijsku zastupljenost šumarstva u godini obilježavanja 260 godina hrvatskog šumarstva.
- Predsjednica Ogranka Gospić Valentina Kulaš zatražila je financijsku pomoć središnjice za izdavanje knjige o povijesti ličkog šumarstva i 75 godina rada Ogranka Gospić, predsjednik Ogranka Nova Gradiška Josip Kovačić financijsku pomoć za izdavanje knjige o povijesti šumarstva novogradiškog kraja i 75 godina rada Ogranka Nova Gradiška te predsjednik Ogranka Varaždin financijsku pomoć za izdavanje knjige o 70 godina rada Ogranka Varaždin. Predsjednik Igor Anić rekao je da će HŠD u granicama financijskih mogućnosti podržati izdavanje svih knjiga u vlastitoj nakladi.

Sjednica je završila u 13:40.

HRVATSKO ŠUMARSKO DRUŠTVO HŠD ZAGREB

Zapisnik sastavio tajnik HŠD
Oliver Vlainić

Predsjednik HŠD
Akademik Igor Anić

BRANKO GRBAC (1961. - 2025.)

Milivoj Diklić[1]

U četvrtak, 30. listopada 2025. u 14 sati na mjesnom groblju Kupjak, s tugom, ali i zahvalnošću, oprostili smo se od našeg dragog kolege i prijatelja Branka – čovjeka koji je svojim radom, karakterom i dobrotom ostavio neizbrisiv trag u našoj sredini.

Branko, sin Franje i Mire, rođene Delač, bio je rođeni Goranin – Hrvat, rimokatolik, čovjek dubokih korijena i velikog srca. Osnovnu školu završio je u Skradu, Šumarsku školu u Delnicama 1980. godine, a šumarstvo je studirao na Šumarskom fakultetu u Zagrebu i uspješno diplomirao 1986. godine.

Nakon završenog Šumarskog fakulteta u Zagrebu svoj je radni vijek započeo u tadašnjem Goransko-primorskom šumskom gospodarstvu Delnice, kasnije i u Šumariji Ravna Gora, gdje je obavljao zahtjevne stručne inženjerske poslove u domeni pripreme rada, šumarskog građevinarstva i iskorištavanja šuma. Neko vrijeme obnašao je i dužnost vršitelja dužnosti Upravitelja šumarije.

Bio je jedan od pionira informatike u šumarstvu, čovjek koji je prepoznao snagu tehnologije i primijenio je u praksi. Kao programer specijaliziran za poslovne procesu u šumarstvu, razvijao je aplikacije koje su olakšale i unaprijedile svakodnevni rad, sudjelovao u analizama poslovanja i kreirao interne informatičke sustave, koji su i danas temelj našega rada.

Kao Rukovoditelj Odjela za informatiku UŠP Delnice, vodio je malu, ali vrijednu ekipu djelatnika. Branko je uvijek bio uz svoje ljude, borio se za njihov status i priznavanje, stojeći ispred njih kada je trebalo braniti struku i pravdu. Bio je Rukovoditelj s razumijevanjem, ali i s čvrstinom koju su svi poštovali.

Branko je kao dragovoljac sudjelovao u Domovinskom ratu na ličkom ratištu 1991. i 1992., svoj doprinos nesebično je dao kao sudionik VRO „Oluja" 1995. – uvijek smiren, nesebičan, ponosan, baš kao što je bio i u životu.

Bio je član HŠD-a, ogranka Delnice i UDVDR HŠ Podružnice Delnice. Uvijek pri ruci u pomoći pri aktivnostima Kluba 138. brigade HV Goranskim risovima u Delnicama. Ljubitelj prirode, šume i života, često je sa suprugom Nedom obilazio goranske predjele oko naselja u kojima je živio i boravio i koja je najviše volio: Kupjaka, Ravne Gore, Delnica, bilježeći njihovu ljepotu fotoaparatom.

Uz šumarstvo, velika mu je ljubav bilo pčelarstvo. Posvećen, marljiv, precizan u suradnji s malom pčelinjom zajednicom, koju je obožavao proizvodio je med i pčelinje proizvode vrhunske kvalitete nerijetko ih poklanjajući prijateljima. S velikim zanosom i strašću često je sudjelovao na izložbama, promovirajući pčelarsku zajednicu. Rado je dijelio znanje s mlađim kolegama i pomagao u edukaciji koju je često organizirala UŠP Delnice.

Bio je i čovjek umjetnosti – u mladosti se bavio glazbom, a kasnije i slikarstvom. No iznad svega bio je oličenje dobrote, poštenja i mira.

Dragi Branko, ostavio si iza sebe dubok trag – u šumarstvu, informatici, pčelarstvu, umjetnosti, u zajednici i u svima nama koji smo imali prigodu i sreću s tobom surađivati i učiti.

Neka ti je laka goranska gruda, neka te u nebeskim šumama prati šum jela i smreka, uz zujanje pčelica koje si toliko volio i o kojima si nesebičnom ljubavlju brinuo!

Počivao u miru Božjem!

[1] Milivoj Diklić, dipl. ing. šum., Hrvatske šume d.o.o.

OBJAVLJIVANJE ČLANAKA U ŠUMARSKOM LISTU

Šumarski list je međunarodni, recenzirani, dvomjesečni, tiskani i elektronički časopis u dijamantnom otvorenom pristupu, koji neprekinuto izlazi od 1877. godine. Časopis Šumarski list objavljuje članke iz područja šumarstva, urbanog šumarstva i zaštite prirode, s geografskim naglaskom na Europu i Mediteran. Časopis prima rukopise u sljedećim kategorijama: izvorni znanstveni radovi, pregledni članci, prethodna priopćenja, kratka priopćenja, stručni radovi, recenzije knjiga, društvene vijesti i najave.

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Knjige:
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Foxcroft, L.C., P. Pyšek, D.M. Richardson, P. Genovesi (ur.), 2013: Plant invasions in protected areas: patterns, problems and challenges. Springer, Dordrecht. https://doi.org/10.1007/978-94-007-7750-7

Poglavlja iz knjige:
Forrest, M., C. Konijnendijk, 2005: A history of urban forests and trees in Europe. U (Konijnendijk, C., K. Nilsson, T. Randrup, J. Schipperijn, ur.): Urban forests and trees. Springer, Berlin, Heidelberg, pp. 23–48. https://doi.org/10.1007/3-540-27684-X_3

Članci iz zbornika skupa:
Konijnendijk, C., 1992: Urban forestry and foresters. U (Hummel, J.A., M.P.E. Parren, ur.): Forests: A growing concern. Proceedings of the XIXth International Forestry Students Symposium, Wageningen, The Netherlands, September 30–October 7, 1991, pp. 33–37.

Doktorski radovi:
Vidaković, A., 2025: Morphological and genetic diversity of populations and chemical composition of fruits of European wild pear (*Pyrus pyraster* (L.) Burgsd.) and almond-leaved pear (*P. spinosa* Forssk.) in Croatia. Doktorski rad, Sveučilište u Zagrebu Fakultet šumarstva i drvne tehnologije, Zagreb.

Softver:
R. Core Team, 2022: R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. https://www.R-project.org

Web stranice:
CABI, 2025: Invasive Species Compendium. Wallingford, UK: CAB International. http://www.cabi.org/isc

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Books:
Pernar, N., 2017: Tlo – nastanak, značajke, gospodarenje. Sveučilište u Zagrebu Šumarski fakultet, Zagreb.
Foxcroft, L.C., P. Pyšek, D.M. Richardson, P. Genovesi (eds.), 2013: Plant invasions in protected areas: patterns, problems and challenges. Springer, Dordrecht. https://doi.org/10.1007/978-94-007-7750-7

Chapters in a book:
Forrest, M., C. Konijnendijk, 2005: A history of urban forests and trees in Europe. In (Konijnendijk, C., K. Nilsson, T. Randrup, J. Schipperijn, eds.): Urban forests and trees. Springer, Berlin, Heidelberg, pp. 23–48. https://doi.org/10.1007/3-540-27684-X_3

Conference proceedings papers:
Konijnendijk, C., 1992: Urban forestry and foresters. In (Hummel, J.A., M.P.E. Parren, eds.): Forests: A growing concern. Proceedings of the XIXth International Forestry Students Symposium, Wageningen, The Netherlands, September 30–October 7, 1991, pp. 33–37.

Theses:
Vidaković, A., 2025: Morphological and genetic diversity of populations and chemical composition of fruits of European wild pear (*Pyrus pyraster* (L.) Burgsd.) and almond-leaved pear (*P. spinosa* Forssk.) in Croatia. PhD Thesis, University of Zagreb Faculty of Forestry and Wood Technology, Zagreb, Croatia.

Software:
R. Core Team, 2022: R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. https://www.R-project.org

Websites:
CABI, 2025: Invasive Species Compendium. Wallingford, UK: CAB International. http://www.cabi.org/isc

Slika 1. Nasad aronije zimi, Slavonija.
❐ Figure 1 Aronia plantation in winter, Slavonia (Croatia).

Slika 2. Listovi su naizmjenični, jednostavni, eliptični do obrnuto jajasti, narovašenog ruba, goli, sjajni, odozgo duž srednje žile s crnim žlijezdama, ujesen crveni, 2,5–6 cm dugački, 1,5–3,5 cm široki, peteljka 2–7 mm dugačka. ❐ Figure 2 Leaves are alternate, simple, elliptical to obovate, with crenate margins, glabrous, shiny, adaxial midrib black-glandular; 2.5–6 cm long, 1.5–3.5 cm wide, petiole 2–7 mm long; autumn colour red.

Slika 3. Cvjetovi su dvospolni, entomofilni, bijeli, 1,5 cm široki, u uspravnim, vršnim gronjama. Cvjeta u svibnju, nakon listanja. ❐ Figure 3 Flowers are bisexual, entomophilous, white, 1.5 cm in diameter, in erect, terminal corymbs. It flowers in May, after leafing.

Slika 4. Jezgričasti plodovi su kuglasti, 6–9 mm veliki, crni, sjajni, sočni, jestivi. Dozrijevaju u kolovozu te ubrzo otpadaju, ornitohorni. ❐ Figure 4 Pomes are globose, 6–9 mm in diameter, black, shiny, juicy, edible. Maturing in August, not persistent, ornithochorous.

Aronia melanocarpa (Michx.) Elliott – aronija (Rosaceae)

Rod *Aronia* Medik. sadrži dvije vrste, *A. arbutifolia* (L.) Pers. i *A. melanocarpa* (Michx.) Elliott. Prirodni križanac između tih vrsta je *A.* ×*prunifolia* (Marshall) Rehder. Najpoznatija i najčešće uzgajana je *A. melanocarpa*, čiji je hrvatski naziv kao i naziv roda – aronija. To je listopadni grm tolerantan na niske temperature, koji naraste od 1 do 1,5 (2) m u visinu i prirodno je rasprostranjen u istočnom dijelu Sjeverne Amerike. Aronija se od razmjerno nedavno uzgaja kao voćna vrsta, cijenjena zbog jestivih, crnih plodova. Također se sadi kao ukrasni grm s bijelim cvjetovima u proljeće i crvenom jesenskom bojom listova. Zbog iznimno visokog sadržaja antioksidansa, posebno antocijana, koji je jedan od najviših među voćem, prepoznata je kao tzv. funkcionalna hrana, odnosno supervoće. Plodovi se mogu jesti svježi, ali se zbog trpkog okusa većinom prerađuju u različite proizvode. Aronija je prilagođena kontinentalnoj klimi i tolerira različite uvjete uzgoja. U Hrvatskoj se često uzgaja u voćnjacima.

Aronia melanocarpa (Michx.) Elliott – Black Chokeberry, Aronia Berry (Rosaceae)

The genus *Aronia* Medik. includes two species: *A. arbutifolia* (L.) Pers. (red chokeberry) and *A. melanocarpa* (Michx.) Elliott (black chokeberry). A natural hybrid between these species is the purple chokeberry (*A.* ×*prunifolia* (Marshall) Rehder). The most common and widely used species is the black chokeberry, a cold-hardy deciduous shrub native to the eastern North America which grows from 1 to 1.5 (2) m high. It is grown as a food crop valued for its edible black berries, as well as an ornamental shrub with white flowers in spring and red autumn foliage colour. As a food crop, black chokeberry has attracted interest relatively recently. It is recognized as a so-called functional food or superfruit because of its very high level of antioxidants, especially anthocyanins, which is one of the highest of any fruit. The berries can be eaten fresh, but due to their astringent flavor, they are usually processed into a variety of food products. Black chokeberry is adapted to the continental climate and tolerates a wide range of growing conditions. In Croatia the black chokeberry is often grown in orchards.

Tekst i fotografije: prof. dr. sc. Marilena Idžojtić