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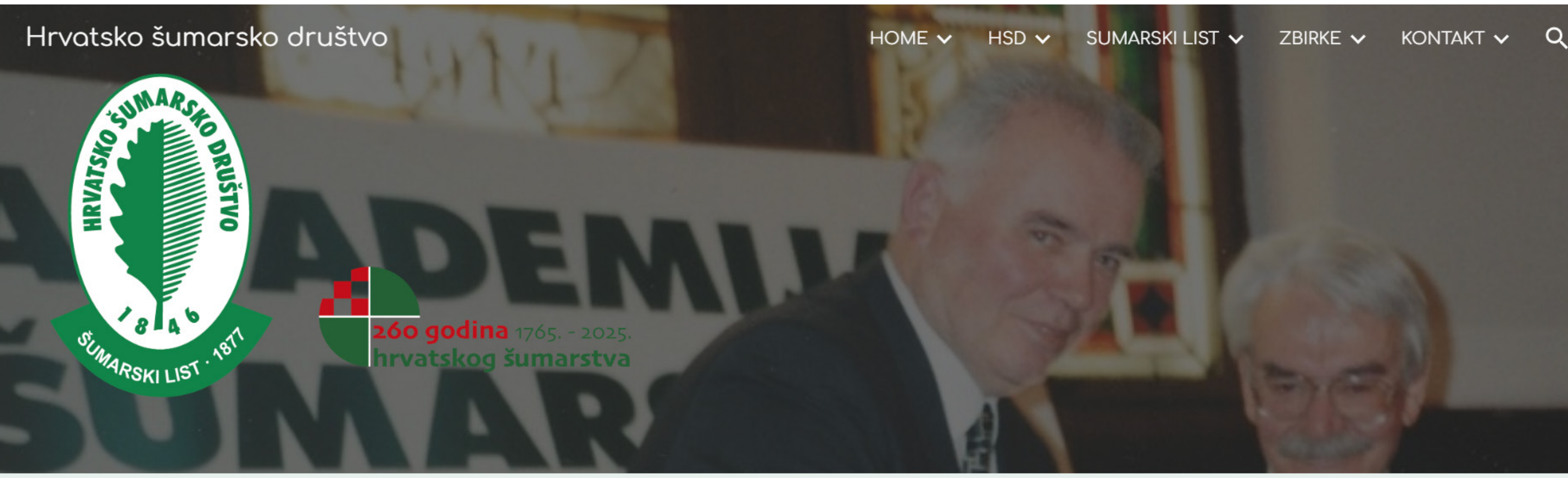

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Najveći hrast lužnjak (*Quercus robur* L.) u Hrvatskoj raste u prašumi Prašnik. (više na str. 479)

The largest oak (*Quercus robur* L.) in Croatia grows in the Prašnik virgin forest. (more on page 479)

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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.

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SADRŽAJ
CONTENTS

Hrvatsko šumarsko društvo

In memoriam

RIJEČ UREDNIŠTVA

NEMA NAPRETKA U ŠUMARSTVU BEZ ZNANOSTI I BEZ KULTURE

Tako glasi posljednja od Deset sentenci o šumi koje je 2004. napisao akademik Dušan Klepac (1917. – 2006.). Nezaboravni sveučilišni profesor i jedan od najvećih šumarskih znanstvenika Sentence je napisao u suton života, promišljajući šume i šumarstvo „u dosadi bolničke postelje".

Danas volimo reći kako se prema Klepčevih Deset sentenci o šumi treba odnositi kao prema deset Božjih zapovijedi. Poseban esej mogao bi se napisati o svakoj od njih. Ovom prilikom osvrnut ćemo se na posljednju sentencu u kojoj je istaknuo kako „nema napretka u šumarstvu bez znanosti i bez kulture".

Šumarstvo je po definiciji znanost, struka i umijeće gospodarenja i očuvanja šuma za trajnu dobrobit čovjeka, društva, okoliša i gospodarstva. Šumarska znanost ima svoj začetak u 18. stoljeću kada je postavljeno načelo o potrajnom gospodarenju šumom razdiobom njezine površine na godišnje sječine. Broj sječina odgovara broju godina ophodnje koji se utvrđuje apsolutnom zrelosti odnosno dobi kulminacije prosječnog dobnog volumnog prirasta. U Hrvatskoj je načelo potrajnog gospodarenja šumom već 1769. ugrađeno u prvi zakon o šumama – Šumski red Marije Terezije.

Intenzivan razvoj šumarske znanosti u nas je počeo 1898. osnutkom Šumarske akademije odnosno današnjeg Fakulteta šumarstva i drvne tehnologije Sveučilišta u Zagrebu. Novi zamah šumarska znanost doživjela je 1945. osnutkom Zavoda za praktična šumarska istraživanja odnosno današnjeg Hrvatskog šumarskog instituta.

Zlatno razdoblje u razvoju šumarske znanosti zbilo se između 1990. i 2013. tijekom kojeg je uspostavljen model petogodišnjeg ugovaranja znanstvenoistraživačkih projekata između šumarskih znanstvenoistraživačkih institucija i poduzeća Hrvatske šume. Model se financirao iz sredstava prikupljenih naknadom za općekorisne funkcije šuma (OKFŠ). Omogućio je temeljna, primijenjena i razvojna istraživanja te objavu vrijednih znanstvenih radova koji su neposredno služili šumarskoj praksi. U tim radovima mogu se pročitati brojne preporuke o gospodarenju šumama u različitim ekološkim, gospodarskim i društvenim prilikama. Hrvatska šumarska znanost i praksa u tom su razdoblju postali pravi primjer međusobnog poticanja i snažnog razvoja koji su doveli do osjetnog poboljšanja stanja šuma i šumarstva Hrvatske.

Danas se financijska potpora struke šumarskoj znanosti odvija kroz malobrojne ciljane istraživačke projekte koji proizilaze iz izabranih praktičnih problema. Od ukupnih godišnje prikupljenih sredstava naknade za OKFŠ tek je 1 % predviđeno za izdvajanje za znanstvene i stručne radove iz područja šumarstva. Taj postotak sve govori. Nedostatak ulaganja u šumarsku znanost osjetit će svaki pažljivi promatrač stanja šuma i šumarstva u Hrvatskoj. Podsjetit ćemo još jednom: nema napretka u šumarstvu bez znanosti i bez kulture.

Uredništvo

EDITORIAL

NO PROGRESS IN FORESTRY WITHOUT SCIENCE AND WITHOUT CULTURE

This is the last of the Ten Sentences on Forests written in 2004 by academician Dušan Klepac (1917–2006). An unforgettable university professor and one of the greatest forestry scientists, Klepac wrote the Sentences at the twilight of his life, reflecting on forests and forestry while "bored in a hospital bed."

Today, foresters like to say that Klepac's Ten Sentences on Forests should be regarded as the Ten Commandments. A separate essay could be written about each of them. On this occasion, we will focus on the final sentence, in which he emphasized that "there is no progress in forestry without science and without culture."

By definition, forestry is the science, profession, and art of managing and preserving forests for the lasting benefit of people, society, environment, and economy. Forestry science had its beginnings in the 18th century, when the principle of sustainable forest management was established by dividing forest land into annual cutting areas. The number of cutting areas corresponds to the number of rotations, which is determined by absolute maturity, i.e., the age at which trees reach their highest average increment. In Croatia, the principle of sustainable forest management was already incorporated in 1769 into the first forest law – Maria Theresa's Forest Order.

The intensive development of forestry science in Croatia began in 1898 with the founding of the Forestry Academy, today's Faculty of Forestry and Wood Technology of the University of Zagreb. A new impetus came in 1945 with the establishment of the Institute for Practical Forest Research, today the Croatian Forest Research Institute.

The golden era of forestry development occurred between 1990 and 2013, during which a model for five-year contracts on scientific research projects between forestry research institutions and the company Croatian Forests was established. The model was financed by funds collected through the fee for the non-market forest goods and services. It enabled fundamental, applied, and developmental research, as well as the publication of valuable scientific papers that directly served forestry practice. These papers contain numerous recommendations for forest management in different ecological, economic, and social conditions. During this period, Croatian forestry science and practice became a true example of mutual encouragement and strong development, which led to a significant improvement of the state of Croatia's forests and forestry.

Today, the financial support between forestry profession and forestry science comes through a small number of targeted research projects derived from selected practical problems. Of the total annual funds collected through the fee for the non-market forest goods and services, only 1% is allocated for scientific and professional work in forestry. The percentage says it all. The lack of investment in forestry science will be noticed by every careful observer of the state of Croatia's forests and forestry. Let us be reminded once again: there is no progress in forestry without science and without culture.

Editorial Board

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Izvorni znanstveni članci – Original scientific papers
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GENETSKA RAZNOLIKOST I GENOTIPIZACIJA KLONOVA U KLONSKOJ SJEMENSKOJ PLANTAŽI CRNOG BORA (*Pinus nigra* J.F.Arnold)

GENETIC DIVERSITY AND GENOTYPING OF CLONES IN CLONAL SEED ORCHARD OF BLACK PINE (*Pinus nigra* J.F.Arnold)

Ida KATIČIĆ BOGDAN[1], Rudolf STIPETIĆ[1], Antonio VIDAKOVIĆ[1], Marko BAČURIN[1], Saša BOGDAN[1], Zlatko ŠATOVIĆ[2], Igor POLJAK[1]*

SAŽETAK

Cilj ovog istraživanja bio je utvrditi raznolikost klonova unutar klonske sjemenske plantaže crnog bora (*Pinus nigra* J.F.Arnold, Pinaceae) na području Šumarije Krk pomoću morfoloških i molekularnih biljega te provesti genetsku identifikaciju (genotipizaciju) rameta kako bi se provjerila točnost nacrta plantaže. U istraživanje su uključeni uzorci 136 rameta iz pet populacija. Molekularne analize provedene su primjenom mikrosatelitskih DNA-biljega, dok je morfometrijska analiza obuhvatila 10 svojstava iglica i češera. Analiza je pokazala statistički značajne razlike među klonovima i populacijama prema svim istraživanim morfološkim svojstvima. Prosječna dužina iglica iznosila je 89,8 mm, dok su češeri, prosječne dužine 55,7 mm i širine 26,8 mm, sadržavali 106 sjemenih ljusaka. U klonskoj sjemenskoj plantaži utvrđeno je 27,2 % pogrešno označenih jedinki (rameta), od kojih su tri pripadale drugim klonovima, dok su ostale imale nepoznate genotipe. Glavni uzroci pogrešaka uključuju odumiranje plemki i rast stabalaca iz podloge, dok su greške u označavanju također moguće. Nacrt plantaže potrebno je ispraviti kako bi se pogrešno označene ramete pravilno označile, a jedinke nepoznatog porijekla i genotipa trebalo bi ukloniti. Buduće plemke za nadopunjavanje plantaže, u slučaju njenog daljnjeg održavanja, trebaju se uzimati sa sada potvrđenih rameta. Kod primjeraka s niskom rašljom koji su za dvije grane imali različite genotipove od kojih samo jedan pripada klonu po nacrtu treba odstraniti granu s krivim genotipom jer je potjerala iz podloge. U usporedbi s drugim istraživanjima s mikrosatelitskim biljezima na crnom boru, genetska raznolikost u plantaži (H_E = 0,646) pokazala je vrijednosti slične prirodnim populacijama. Klonovi u plantaži porijeklom su iz malog broja populacija od kojih su neke vrlo slabo zastupljene pa se u slučaju održanja plantaže preporuča proširiti genetsku bazu novoselekcioniranim klonovima. Multivarijatnim statističkim metodama nije utvrđeno grupiranje klonova temeljem njihove pripadnosti izvornim populacijama. Dobiveni rezultati ovog istraživanja imaju značajnu praktičnu vrijednost za šumarsku struku jer sjemenske plantaže čine prikladnu bazu za *ex situ* očuvanje genetske raznolikosti vrste te za proizvodnju genetski kvalitetnog sjemena za obnovu sastojina ili potpomaganje prirodne obnove. Ovo istraživanje također ukazuje na važnost točnog označavanja klonova kako bi se izbjegle negativne posljedice u gospodarenju klonskim sjemenskim plantažama.

KLJUČNE RIJEČI: crni bor, morfometrijska analiza, genetska analiza, mikrosateliti, klonska sjemenska plantaža, očuvanje genofonda

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UVOD
INTRODUCTION

Nabava šumskog sjemena za potpomaganje prirodne obnove može se provoditi na nekoliko načina, pri čemu kriteriji za odabir mjesta sakupljanja ili šumskog sjemenskog objekta (ŠSO-a) određuju svrstavanje prikupljenog sjemena u različite kategorije.

Sjeme za potrebe šumarstva može se proizvoditi na više načina. Najjednostavniji je način sabiranje sjemena u šumi ili izvan šume s pojedinačnih stabala koja se slobodno oprašuju, a da se pri tome ne obrati posebna pažnja na kvalitetu stabala, genetsku i tehničku, s kojih se sabire sjeme, niti se ne izdvajaju iz daljnje proizvodnje fenotipski loša stabla. Od tako sakupljenog sjemena ne možemo očekivati dobro, a često puta niti prosječno potomstvo. Stoga se ovako proizvedeno i sakupljeno sjeme ne koristi u šumarstvu za biološku obnovu šuma. Umjesto toga, biraju se dijelovi kvalitetnijih šuma koje se svrstavaju u kategoriju „poznato podrijetlo". Drugi način je sakupljanje sjemena u odabranim kvalitetnim sastojinama – sjemenskim sastojinama. Dobiveno sjeme ima u prosjeku bolju genetsku konstituciju jer se prikuplja isključivo s fenotipski kvalitetnih stabala. Potomstvo proizvedeno od takvog sjemena, u genetskom smislu, trebalo bi biti barem na razini prosjeka sjemenske sastojine iz koje je sjeme prikupljeno (kategorija „selekcioniran"). Treća metoda proizvodnje šumskog sjemena odvija se u tzv. sjemenskim plantažama (kategorija „kvalificiran").

U programima oplemenjivanja određenih svojti šumskog drveća koje se ne mogu rutinski razmnožavati autovegetativno, klonske sjemenske plantaže imaju ključnu ulogu. Klonske sjemenske plantaže predstavljaju skupinu genetski superiornih stabala koja se intenzivno održavaju kako bi se osigurala učestala i obilna cvatnja te redovita rodnost. Njihov je cilj zadovoljiti povećane potrebe u proizvodnji šumskog reprodukcijskog materijala.

Pod sjemenskom plantažom podrazumijeva se kultura genetski superiornih stabala koja su izolirana ili posebno uređena kako bi se izbjeglo ili znatno smanjilo oprašivanje iz vanjskih izvora genetski inferiornih stabala. Plantažom se intenzivno gospodari u vidu zaštite od štetnika i vremenskih nepogoda, gnojidbe i navodnjavanja, sa svrhom učestale i obilne cvatnje i sjemenonošenja. Fenotipski najkvalitetnija stabla, tzv. plus stabla, u plantaži se međusobno oprašuju i oplođuju, čime se ostvaruje genetska dobit. Tako proizvedeni šumski reprodukcijski materijal pripada kategoriji „kvalificiran". Daljnje poboljšanje genetske kvalitete sjemena i biljaka ostvaruje se selekcijom po genotipu kroz testove potomstva. Takav šumski reprodukcijski materijal svrstava se u kategoriju „testiran". Na osnovi testiranja potomstva iz plantaže uklanjaju se klonovi (majčinska plus stabla) koja daju ispodprosječno potomstvo. Nakon selekcije plus stabala provodi se njihovo heterovegetativno razmnožavanje (cijepljenje), osnivanje i nadopunjavanje sjemenskih plantaža cijepovima (rametama) te njega biljaka i oblikovanje krošnji. Ujedno se provodi zaštita od bolesti i štetnika, praćenje vremena listanja, fruktifikacije i sjemenonošenja klonova. Monitoring nam daje ključne informacije o zakonitostima i problemima sjemenonošenja u plantažama. Genetska kvaliteta selekcioniranih stabala (plus stabala) ispituje se putem testova potomstva, a klonske sjemenske plantaže služe i kao arhivi za očuvanje genetskih resursa vrste.

Ako se provode propisane mjere, proizvodnja sjemena u plantaži je veća i češća nego u prirodnim sastojinama i kulturama. Zahvaljujući tome, planirane potrebe za sjemenom mogu se lakše ostvariti. Sakupljanje sjemena u plantaži jednostavnije je jer se radi o modificiranim stablima uzgojenima za fruktifikaciju i sjemenonošenje, smještenima na odgovarajućoj i prethodno pripremljenoj površini. Pravilnim odabirom lokaliteta za podizanje sjemenske plantaže može se dodatno povećati učestalost rodnosti i poboljšati kvaliteta sjemena. Druga vrlo važna uloga sjemenskih plantaža je veća genetska dobit u potomstvu nego što je to kod sjemenskih sastojina ili šumskih sastojina. Naime, u sjemenskim plantažama provodi se polukontrolirano oprašivanje, a sjeme potječe od selekcioniranih i poznatih roditelja. S druge strane, u sjemenskim sastojinama poznata je samo majčinska jedinka s koje se sjeme prikuplja, dok su očevi nepoznati. Zahvaljujući tome, sjeme proizvedeno u plantaži ima garantirano visoku genetsku kvalitetu.

Iako je u gospodarenju hrvatskim šumama predviđena prirodna obnova, ona se ne može uvijek u potpunosti provesti. Najčešći razlog tome je nedostatak uroda u sastojinama koje se trebaju prirodno pomladiti. Godišnje potrebe za sjemenom važnijih svojti šumskog drveća pokazuju znatan godišnji manjak. Kako bi se smanjila ili potpuno uklonila ova negativna razlika između potrebnog i prikupljenog sjemena, nužno je poboljšati organizaciju proizvodnje sjemena. U tom kontekstu, proizvodnja sjemena u sjemenskim plantažama trebala bi nam pružiti bolja rješenja. Upravo s tom idejom, 2004. godine osnovana je klonska sjemenska plantaža crnog bora (*Pinus nigra* J.F.Arnold, Pinaceae) na otoku Krku.

Crni bor raste na suhim staništima, pretežito na vapnenačkim tlima, dolomitima i terasastim površinama, na južnim ekspozicijama brdskog i gorskog pojasa (Vidaković 1993, Enescu i dr. 2016). Ova vrsta uspijeva u čistim ili mješovitim sastojinama, najčešće na nadmorskoj visini od 250 do 1500 (2200) metara. Crni bor ima izrazito diskontinuiran areal i općenito je rasprostranjen u južnoj Europi, sjeverozapadnoj Africi, Maloj Aziji, Krimu i Cipru. U Hrvatskoj se smatra reliktom tercijara (Bogunić i dr. 2007), koji je u pliocenu rastao na područjima gdje raste i danas. Pretežno raste u čistim sastojinama na kamenitim i sunčanim padinama zapadnih obronaka Dinarida, na nadmorskoj visini od 350 do 1400 (1600) metara. U Hrvatskoj su prisutne dvije podvrste crnog bora (Liber 2000, Liber i dr. 2003, Scotti-Saintagne i dr. 2019): tipska podvrsta (*Pinus nigra* subsp. *nigra*) te endemična podvrsta, dalmatinski crni bor (*P. nigra* subsp. *dalmatica* (Vis.) Franco). Dalmatinski crni bor raste na vrhovima srednjodalmatinskih i južnodalmatinskih otoka Brača, Hvara i Korčule, kao i na poluotoku Pelješcu. Istraživanja genetske raznolikosti crnog bora pomoću jezgrenih mikrosatelita nisu brojna. Očekivana heterozigotnost (H_E) za portugalske prirodne populacije (Dias i dr. 2020), analizirane s 13 mikrosatelita, od kojih su neki bili izrazito polimorfni, iznosila je 0,76. U istraživanju Giovanelli i dr. (2017) s korištenih 14 mikrosatelita H_E se kretao u rasponu od 0,576 do 0,717 u devet populacija, s tim da je hrvatska populacija (dalmatinski crni bor) imala H_E od 0,660.

Crni bor je heliofilna i kserofitna vrsta koja u mladosti raste relativno brzo (Herman 1971). Otporan je na vjetrove i sušu, a dobro podnosi i gradske uvjete. Osim toga, značajan je i kao ukrasna vrsta koja se široko uzgaja te često koristi za sadnju u parkovima. Najvažnija je vrsta bora za pošumljavanje submediteranskog krša (Isajev i dr. 2004) zbog čega je ključno osigurati pouzdan i genetski kvalitetan izvor reprodukcijskog materijala.

Za analizu genetske raznolikosti, kao i genetsku identifikaciju jedinki u plantažama, često se koriste jezgreni mikrosateliti kao molekularni ili, preciznije rečeno, DNA biljezi. Mikrosatelitski biljezi predstavljaju dijelove DNA u kojima se neki nukleotidni slijed, obično od 1-6 parova baza, ponavlja određeni broj puta. Njihova je značajka velika mutacijska stopa i s njom povezana velika polimorfnost DNA na tim dijelovima genoma kod različitih jedinki u analizi. Uobičajeno je raznolikost mikrosatelitskih lokusa kod različitih jedinki u analizi nazvati različitim alelima na tom mikrosatelitskom lokusu. Zbog svoje polimorfnosti analiza većeg broja mikrosatelitskih lokusa (biljega) prikladna je za točnu genetsku identifikaciju jedinki (genotipizaciju). Osim za genotipizaciju, mikrosatelitski biljezi prikladni su za istraživanje genetske raznolikosti unutar i između populacija, istraživanje migracije gena između populacija, obrazaca razmnožavanja unutar populacija te za utvrđivanje roditelja.

Cilj ovog rada bio je utvrditi raznolikost klonova unutar klonske sjemenske plantaže crnog bora na području Šumarije Krk primjenom morfoloških i DNA biljega. Analizom morfoloških biljega utvrđena je raznolikost među pojedinim rametama klona, između klonova, kao i među izvornim populacijama. Primjenom mikrosatelitskih DNA biljega provedena je genetska identifikacija (genotipizacija) klonova, a također je utvrđena pripadnost rameta klonovima prema unaprijed utvrđenom planu i nacrtu njihova položaja unutar klonske sjemenske plantaže.

MATERIJALI I METODE
MATERIALS AND METHODS

Područje istraživanja - *Research area*

Klonska sjemenska plantaža crnog bora nalazi se u sklopu gospodarske jedinice Lug na otoku Krku i u nadležnosti je Šumarije Krk. Sa svih strana okružena je gospodarskom jedinicom Kras–Gabonjin. Plantaža se nalazi na nadmorskoj visini od približno 10 metara i udaljena je oko 10 kilometara od prirodnih šuma crnog bora. Ukupna površina plantaže iznosi 2,0 hektara. Godine 2004. u rasadniku su uzgajane podloge, na koje su zatim cijepljene ramete jednog plus stabla s područja Šumarije Krk. Ostale ramete, njih 31, heterovegetativno su razmnožene (precijepljene) iz klonske sjemenske plantaže crnog bora u Prkosu (UŠP Gospić). U listopadu 2006. na prethodno obrađenoj površini zasađene su ramete 32 klona, ukupno njih 157. Do 2023. godine u plantaži su ostale prisutne 132 ramete. Razmak između redova, kao i između rameta unutar reda, iznosi 10 metara (10 × 10 m). Podaci o plus stablima crnog bora u klonskoj sjemenskoj plantaži prikazani su u Tablici 1.

Tablica 1. Podaci o plus stablima crnog bora u klonskoj sjemenskoj plantaži.
Table 1 Data on plus trees included in the clonal seed orchard of black pine.

Broj klona *Clone number*	Geografsko porijeklo klona (Šumarija, G.J., ŠP odjel/odsjek; lokalitet) *Geographical origin of the clone (Forest administration data)*
1	Vrhovine, Samar, 8
2	Vrhovine, Samar, 8
3	Vrhovine, Samar, 8
4	Vrhovine, Samar, 8
5	Vrhovine, Samar, 8
9	Vrhovine, Samar
6	Vrhovine, Samar, 8
7	Vrhovine, Samar, 8
8	Šipovo, Donji Janj, Sastavci Palež 61
10	Krk, Obzova, 121a
11	Vrhovine, Samar, 8
12	Vrhovine, Samar, 8
13	Vrhovine, Samar, 8
14	Vrhovine, Samar, 8
15	Vrhovine, Samar, 8
16	Vrhovine, Samar, 8
17	Vrhovine, Samar, 8
18	Vrhovine, Samar, 8
19	Vrhovine, Samar, 8
20	Vrhovine, Samar, 8
21	Labin, Smolići, Ripenda
22	Delnice, Klana, Škalnica 18
23	Delnice, Klana, Brdo
24	Vrhovine, Samar, 8
25	Vrhovine, Samar, 8
26	Vrhovine, Samar, 8
27	Vrhovine, Samar, 8
28	Šipovo, Donji Janj, Sastavci Palež 61
29	Šipovo, Donji Janj, Jašev Begova kosa
30	Šipovo, Donji Janj, Jašev Begova kosa
31	Šipovo, Donji Janj, Sastavci Palež 61
32	Šipovo, Donji Janj, Jašev Begova kosa

Biljni materijal - *Plant material*

Materijal za morfometrijsku i molekularnu analizu sakupljen je u proljeće 2023. godine sa svih rameta koje se nalaze na plantaži. U slučaju rameta koje su imale dvije glavne grane (rašlja) koje su se granale nisko iz debla, posebno su uzorkovane obje grane kao zasebni uzorci, kako bi se provjerilo jesu li istog genotipa. Za potrebe molekularne analize uzorkovane iglice su pohranjene u silika gelu do izolacije DNA. Za morfometrijsku analizu sa svake ramete sakupljeno je po 20 zdravih i neoštećenih iglica iz vanjskog osunčanog dijela krošnje. Na biljkama koje su imale češere sakupljeno je po 10 češera. Uzorci za morfometrijsku analizu na terenu su pohranjeni u plastične vrećice. Po povratku s terena iglice su herbarizirane, a češeri su pohranjeni u hladnjak do daljnje analize. Za morfometrijsku analizu iglica i molekularnu analizu sakupljeni su uzorci sa 136 biljaka, a za morfometrijsku analizu češera s 87 biljaka.

Morfološka analiza - *Morphological analysis*

Morfološka analiza iglica i češera - *Morphological analysis of needles and cones*

Iglice su skenirane A3 skenerom (MICROTEK ScanMaker 9800XL) pri čemu je korištena razlučivost od 600 dpi (TIF datoteka). Nakon skeniranja, izmjerene su softverskim paketom WINFOLIA PRO (2005) korištenjem opcije Leaf Morphology. Točnost mjerenja iznosila je 0,1 mm, a za svaku iglicu određena je dužina (NL) i njezina najveća širina (NW). Osim toga, korištenjem opcije Interactive Measurements određena je i dužina rukavca (NSL).

Digitalnim pomičnim mjerilom određena su sljedeća morfološka svojstva češera: dužina češera (CL), najveća širina češera (CW), visina štitića (AL), širina štitića (AW), debljina štitića (AT) i dužina mjerena od sredine grbice do vrha štitića (DAU). Osim toga, za svaki češer određen je i ukupni broj sjemenih ljusaka (CSN).

Statistička analiza morfoloških podataka - *Statistical analysis of morphological data*

Za potrebe statističke obrade podataka upotrijebljene su standardne deskriptivne i multivarijatne statističke metode (Sokal i Rohlf 1989, McGarigal i dr. 2000) unutar programskog paketa Statistica for Windows (StatSoft, Inc. 2001). Za svaku istraživanu značajku određeni su sljedeći deskriptivni statistički pokazatelji: aritmetička sredina (M) i standardna devijacija (SD). Odnos između mjerenih značajki češera i iglica utvrđen je Spearmanovim koeficijentom korelacije. Kako bi se utvrdile razlike između klonova i izvornih populacija korištena je Kruskal-Wallis ANOVA.

Kako bi se dodatno pojasnio trend variranja morfoloških svojstava i izvornih populacija primijenjena je analiza glavnih sastavnica. Ulazni podaci prethodno su standardizirani z-score metodom, a sve analize provedene su pomoću računalnog programa R v.3.2.2 (R Core Team 2016) i funkcija unutar MorphoTools R scripts (Koutecký 2015).

Analiza pomoću molekularnih biljega - *Analysis with molecular markers*

Izolacija DNA - *DNA extraction*

Ukupna stanična DNA svakog pojedinog uzorka izolirana je iz 50 mg osušenog lisnog tkiva. Prije izolacije DNA tkivo je smrznuto u tekućem dušiku i usitnjeno pomoću uređaja Tissuelyser (Qiagen). Za izolaciju ukupne stanične DNA upotrjebljen je DNeasy® Plant Pro Kit (250) (Qiagen) komplet. Ovaj izolacijski komplet namijenjen je za izolaciju DNA iz problematičnih uzoraka koji zbog sadržaja inhibirajućih spojeva poput polifenola obično daju slabiji prinos DNA pri standardnim izolacijama.

Molekularni biljezi - Molecular markers

Mikrosatelitski lokusi umnoženi su lančanom reakcijom polimerazom (PCR) upotrebom pet pari početnica opisanih u Ganea i dr. (2015). Ovi mikrosatelitski biljezi su razvijeni za primjenu kod običnog bora (*Pinus sylvestris* L.), ali autori navode da su testirani i na crnom boru te da su primjenjivi i za genotipizaciju ove vrste. Značajke upotrjebljenih mikrosatelitskih biljega prikazane su u Tablici 2.

Lančana reakcija polimerazom (PCR) - *Polymerase chain reaction (PCR)*

Za umnožavanje mikrosatelitskih lokusa lančanom reakcijom polimerazom upotrjebljen je komercijalni komplet za PCR (Type-it Microsatellite PCR kit, Qiagen) po uputama proizvođača. Forward početnice označene su na 5' kraju fluorescentnim oznakama za detekciju kapilarnom elektroforezom (Tablica 2). Ukupni volumen reakcije po

Tablica 2. Mikrosatelitni biljezi korišteni u analizi, florescencijska oznaka, ponavljajući motivi i očekivani raspon alela.
Table 2 Molecular markers used in the analysis, fluorescent label, repeat motifs and expected allele ranges.

Biljeg *Marker*	Oznaka na F početnici *F primer dye*	Ponavljajući motiv *Repeat motif*	Očekivani raspon alela (*Pinus sylvestris* L.) *Allele range (Pinus sylvestris L.)*
PtTx3013	6-FAM	GTT	90–120
PtTx3020	VIC	A(CAA)	150–170
PtTx3049	VIC	TG	280–320
SPAC12.5	6-FAM	(GT)(GA)	130–210
PtTx3107	NED	CAT	140–160

pojedinom uzorku bio je 10 µl. Za umnožavanje mikrosatelitskih lokusa upotrjebljen je Touchdown protokol naveden u Ganea i dr. (2015), na uređaju MasterCycler gradient (Eppendorf). Analiza fragmenata kapilarnom elektroforezom provedena je pomoću Macrogen Europe. Duljine alela očitane su u programu GeneMapper™ Software 5 (Thermo Fisher Scientific).

Statistička analiza molekularnih podataka - *Statistical analysis of molecular data*

Genetska identifikacija (genotipizacija) klonova u plantaži - *Genetic identification of clones in the clonal seed orchard*

Ramete istog klona trebale bi dijeliti isti genotip. Ukoliko se primijeti da neka rameta ne pripada klonu kojem bi trebala pripadati, izdvojena je iz rameta tog klona i naznačena kao greška u nacrtu. Ukoliko se ustanovi da krivo dodijeljena jedinka po genotipu pripada drugom klonu, pridružena je tom klonu. Ukoliko genotip takve jedinke nije pripao ni jednom klonu, izdvojen je iz daljnjih analiza.

Raznolikost mikrosatelitskih biljega - *Microsatellite markers diversity*

Za svaki mikrosatelitski lokus određeni su broj alela po lokusu (N_a), informacijski sadržaj polimorfizma (PIC) i vjerojatnost identiteta (probability of identity) (PI) koristeći računalni program Cervus v3.0 (Kalinowski i dr. 2007).

Raznolikost genotipova klonova u klonskoj sjemenskoj plantaži - *Genetic diversity of clones in the clonal seed orchard*

Unutarpopulacijska raznolikost klonova procijenjena je pomoću računalnog programa GenAlEx 6.5. (Peakall i Smouse 2012). Izračunati su prosječni broj alela (N_{av}), primijećena (H_O) i očekivana (H_E) heterozigotnost te koeficijent inbridinga (F_{IS}) za sve klonove iz plantaže. Klasterska analiza matrice genetičke udaljenosti dobivene izračunom udjela zajedničkih alela (proportion of shared alleles, PSA) provedena je metodom Neighbor-joining u računalnom potprogramu NEIGHBOR paketa PHYLIP v3.698 (Felsenstein 2004).

REZULTATI

RESULTS

Morfološka analiza - *Morphological analysis*

Deskriptivna statistika - *Descriptive statistics*

Rezultati deskriptivne statističke analize za pojedine klonove prikazani su u Tablici 3, dok su za izvorne populacije prikazani u Tablici 4. Prosječna dužina češera svih stabala na klonskoj sjemenskoj plantaži iznosila je 55,7 mm, dok je njihova širina bila 26,8 mm. Češeri su u prosjeku imali 106 sjemenih ljusaka. Dužina iglica svih istraživanih stabala iznosila je 89,8 mm, njihova širina bila je 1,09 mm, dok je dužina rukavca bila 6,66 mm. Provedenom Kruskal-Wallis analizom varijance utvrđeno je da se klonovi i izvorne populacije statistički značajno razlikuju prema morfološkim svojstvima iglica i češera.

Promatrajući morfološka svojstva češera na razini izvornih populacija, uočava se da su češeri klonova podrijetlom s Krka najduži (62,7 mm) i najširi (29,7 mm), dok su najkraći (51,4 mm) i najuži (26,2 mm) kod klonova podrijetlom iz Labina. Sjemene ljuske bile su najšire (11,0 mm) kod klonova podrijetlom iz Delnica, a najuže (9,46 mm) kod onih podrijetlom s Krka, koji su istovremeno imali i najkraće sjemene ljuske (6,56 mm). S druge strane, najduže sjemene ljuske (7,70 mm) bile su karakteristične za klonove podrijetlom iz Vrhovina. Udaljenost od sredine grbice do vrha štitića bila je najveća kod klonova iz Delnica i Vrhovina (3,51 mm), a najkraća kod klonova iz Labina (3,16 mm). Klonovi podrijetlom s Krka imali su i najveći broj sjemenih ljusaka (141), dok su klonovi iz Delnica imali najmanji broj (102). Iglice su bile najduže (97,6 mm) i najšire (1,14 mm) kod klonova podrijetlom iz Delnica, dok je najduži rukavac bio zabilježen kod klonova s Krka (7,50 mm). S druge strane, najkraće iglice (78,6 mm) i najkraći rukavac (6,08 mm) zabilježeni su kod klonova iz Šipova, dok su najuže iglice (0,99 mm) zabilježene kod klonova iz Labina.

Korelacijska analiza - *Correlation analysis*

Rezultati korelacijske analize prikazani su u Tablici 5. Od ukupno 45 parova, statistički značajne korelacije utvrđene su za 33 para, od kojih su samo dva para bila u značajnoj negativnoj korelaciji: broj sjemenih ljuski (NS) i visina štitića (AH) te broj sjemenih ljuski (NS) i udaljenost od sredine grbice do vrha štitića (DAU). Najviše značajnih korelacija bilo je zabilježeno za svojstvo udaljenost od sredine grbice do vrha štitića (DAU), koje je bilo značajno korelirano sa svim ostalim mjerenim morfološkim svojstvima. Slijedile su širina češera (CW), visina štitića (AH) i dužina iglice (NL), s osam značajnih korelacija. Najmanje značajnih korelacija, njih četiri, bilo je zabilježeno za broj sjemenih ljuski (NS) i debljinu štitića (AT).

Analiza glavnih sastavnica - *Principal component analysis*

Analizom glavnih sastavnica utvrđeno je da prve četiri glavne sastavnice objašnjavaju 88,5 % ukupne varijabilnosti. Svojstvene vrijednosti za prve tri glavne sastavnice bile su veće od 1. U Tablici 6 prikazane su korelacije između prve četiri glavne sastavnice i svih istraživanih svojstava češera i iglica. Slika 1 prikazuje dijagram u kojem su u koordinatnom sustavu točkama prikazani položaji analiziranih klonova temeljem njihove pripadnosti izvornim populacijama, dok su istraživana morfološka svojstva prikazana vektorima. Iz priložene

Tablica 3. Rezultati deskriptivne statistike za mjerena morfološka svojstva češera i iglica, prikazani po klonovima. Morfološka svojstva: CL–dužina češera (mm); CW–širina češera (mm); AW–širina štitića (mm); AH–visina štitića (mm); DAU–udaljenost od sredine grbice do vrha štitića (mm); NS–broj sjemenih ljusaka; AT–debljina štitića (mm); NL–dužina iglice (mm); NSL–dužina rukavca (mm); NW–širina iglice (mm). Deskriptivni pokazatelji: M–aritmetička sredina; SD–standardna devijacija. Crvenom bojom označene su najveće prosječne vrijednosti, a zelenom najmanje.

Table 3 The results of descriptive statistics for measured cone and needle morphological traits, showed per clones. Morphological traits: CL–cone length (mm); CW–cone width (mm); AW–width of cone scale apophysis (mm); AH–height of cone scale apophysis (mm); DAU–distance between umbo and scale top (mm); NS–number of cone scales; AT–thickness of cone scale apophysis (mm); NL–needle length (mm); NSL–basal sheath length (mm); NW–needle width (mm). Descriptive parameters: M–arithmetic mean; SD–standard deviation. The highest average values are marked in red, while the lowest are marked in green.

Klon *Clone*	Porijeklo *Origin*	Deskriptivni pokazatelj *Descriptive parameter*	Svojstvo / *Trait*									
			CL	CW	AW	AH	DAU	NS	AT	NL	NSL	NW
1	Vrhovine	M	52,2	29,2	10,3	6,81	3,19	122	3,58	103	7,63	1,16
		SD	3,61	1,75	0,88	0,83	0,40	12	0,31	13,6	0,73	0,12
2	Vrhovine	M	53,1	29,7	11,1	8,47	4,06	91	3,90	124	7,86	1,28
		SD	5,61	2,51	1,32	0,82	0,59	6	0,43	10,0	0,70	0,19
3	Vrhovine	M	61,3	27,6	9,43	6,09	3,15	143	2,97	80,2	7,40	1,13
		SD	5,29	0,73	1,41	0,94	0,51	14	0,21	8,40	0,83	0,09
4	Vrhovine	M	62,6	26,2	11,0	9,02	3,80	102	3,92	88,9	6,78	1,08
		SD	7,62	2,51	1,58	1,02	0,39	7	0,48	15,3	0,89	0,17
5	Vrhovine	M	63,5	26,9	10,7	7,69	3,44	97	3,12	104	7,48	1,10
		SD	9,21	3,01	1,69	1,17	0,45	10	0,36	25,7	1,33	0,12
6	Vrhovine	M	54,8	27,8	10,3	8,46	3,64	104	3,58	95,4	7,48	1,02
		SD	6,3	2,61	1,01	0,84	0,42	9	0,37	9,70	0,91	0,12
7	Vrhovine	M	49,8	25,9	10,2	8,92	4,11	84	3,82	89,5	6,28	1,21
		SD	3,94	1,5	0,61	0,82	0,38	9	0,48	8,80	0,77	0,14
8	Vrhovine	M	50,9	25,4	10,3	6,31	2,92	99	2,83	60,9	5,31	0,86
		SD	3,91	1,35	0,9	0,75	0,28	7	0,17	7,90	0,60	0,08
9	Vrhovine	M	58,5	24,4	10,2	7,67	3,47	108	3,04	93,5	5,81	1,09
		SD	5,64	1,89	0,86	0,69	0,47	10	0,28	10,70	0,71	0,12
10	Krk	M	62,7	29,7	9,46	6,56	3,25	141	3,20	95,0	7,50	1,05
		SD	3,72	1,83	1,1	0,41	0,35	18	0,28	9,90	1,30	0,10
11	Vrhovine	M	50,2	25,9	10,2	7,22	3,30	93	3,24	91,2	6,47	1,14
		SD	4,08	1,95	0,78	0,65	0,32	6	0,27	9,30	1,08	0,07
12	Vrhovine	M	51,1	28,8	9,98	6,76	3,10	102	3,07	80,6	5,71	1,00
		SD	7,75	1,92	1,4	1,18	0,63	5	0,42	12,8	0,84	0,10
13	Vrhovine	M	63,3	29,2	11,7	8,81	4,05	104	3,64	96,0	7,15	1,19
		SD	8,01	3,58	1,44	1,12	0,55	10	0,36	14,6	0,82	0,12
14	Vrhovine	M	58,5	28,5	11,5	7,65	3,67	98	3,51	102	7,28	1,20
		SD	6,13	1,96	1,13	0,73	0,31	8	0,34	8,30	0,83	0,11
15	Vrhovine	M	67,5	28,4	11,3	8,85	4,07	102	3,40	89,2	6,39	1,06
		SD	6,51	1,99	0,76	0,77	0,44	10	0,22	14,2	0,74	0,09
16	Vrhovine	M	59,2	29,0	11,7	7,28	3,48	122	3,60	93,0	6,61	1,05
		SD	7,74	2,46	1,42	0,84	0,51	12	0,34	20,2	0,76	0,08
18	Vrhovine	M	53,2	22,0	10,5	8,27	3,59	83	3,03	98,7	6,68	1,11
		SD	9,92	3,23	1,42	1,00	0,40	10	0,38	14,9	0,85	0,09
19	Vrhovine	M	45,1	22,5	8,97	6,66	3,09	78	3,07	108	6,25	1,07
		SD	4,4	1,67	0,85	0,74	0,52	7	0,24	8,90	0,91	0,04
20	Vrhovine	M	53,0	26,8	10,0	6,90	3,15	111	3,56	77,0	6,39	1,06
		SD	5,98	2,34	0,87	0,79	0,35	9	0,28	11,6	0,66	0,09
21	Labin	M	51,4	26,2	10,4	6,64	3,16	111	3,27	86,2	6,34	0,99
		SD	4,57	2,6	1,16	0,86	0,33	15	0,25	22,1	0,92	0,12
22	Delnice	M	56,5	28,8	11,0	7,72	3,40	97	3,21	97,2	7,12	1,16
		SD	7,54	3,43	1,58	1,02	0,35	5	0,39	8,70	0,91	0,07
23	Delnice	M	62,8	28,3	11,0	7,55	3,57	104	3,26	98,0	7,07	1,13
		SD	5,73	1,84	0,94	0,81	0,44	8	0,27	17,2	1,00	0,16
24	Vrhovine	M	49,7	24,2	9,28	7,89	3,43	94	3,11	84,3	6,17	1,04
		SD	3,46	0,98	0,48	0,57	0,44	7	0,28	9,7	0,99	0,09
25	Vrhovine	M	52,0	25,8	9,02	6,15	2,87	126	3,08	78,7	6,20	1,10
		SD	5,96	2,06	0,83	0,79	0,45	13	0,30	16,5	0,96	0,12
26	Vrhovine	M	54,4	27,5	8,91	8,05	3,98	115	3,35	89,5	7,23	1,10
		SD	6,45	2,55	0,97	0,58	0,44	8	0,28	12,1	0,91	0,10
28	Šipovo	M	54,0	26,1	9,22	6,46	3,09	129	3,04	85,6	6,64	1,14
		SD	4,78	1,90	0,87	0,60	0,35	12	0,29	16,1	0,84	0,12
30	Šipovo	M	52,4	29,3	9,57	6,81	3,13	101	3,35	95,3	6,45	1,10
		SD	6,29	2,32	1,18	0,65	0,37	7	0,42	16,2	1,11	0,08
31	Šipovo	M	50,9	25,8	11,0	9,32	4,25	80	3,68	102	6,66	1,25
		SD	6,37	2,47	1,4	1,27	0,55	8	0,31	8,9	0,62	0,08
32	Šipovo	M	49,8	23,9	8,98	7,08	3,33	116	3,59	58,2	5,53	0,99
		SD	4,51	1,67	1,09	0,66	0,29	5	0,36	11,8	0,78	0,14
Ukupno *Total*		M	55,8	26,8	10,3	7,51	3,45	106	3,36	89,8	6,66	1,09
		SD	8,15	2,97	1,42	1,27	0,56	17	0,44	19,4	1,09	0,14

Tablica 4. Rezultati deskriptivne statistike za mjerena morfološka svojstva češera i iglica, prikazani po lokalitetima. Morfološka svojstva: CL–dužina češera (mm); CW–širina češera (mm); AW–širina štitića (mm); AH–visina štitića (mm); DAU–udaljenost od sredine grbice do vrha štitića (mm); NS–broj sjemenih ljusaka; AT–debljina štitića (mm); NL–dužina iglice (mm); NSL–dužina rukavca (mm); NW–širina iglice (mm). Deskriptivni pokazatelji: M–aritmetička sredina; SD–standardna devijacija. Crvenom bojom označene su najveće prosječne vrijednosti, a zelenom najmanje.

Table 4 The results of descriptive statistics for measured cone and needle morphological traits, showed per locality. Morphological traits: CL–cone length (mm); CW–cone width (mm); AW–width of cone scale apophysis (mm); AH–height of cone scale apophysis (mm); DAU–distance between umbo and scale top (mm); NS–number of cone scales; AT–thickness of cone scale apophysis (mm); NL–needle length (mm); NSL–basal sheath length (mm); NW–needle width (mm). Descriptive parameters: M–arithmetic mean; SD–standard deviation. The highest average values are marked in red, while the lowest are marked in green.

Porijeklo *Origin*	Deskriptivni pokazatelj *Descriptive parameter*	Svojstvo / *Trait*									
		CL	CW	AW	AH	DAU	NS	AT	NL	NSL	NW
Delnice	M	60,8	28,5	11,0	7,61	3,51	102	3,24	97,6	7,09	1,14
	SD	6,96	2,44	1,17	0,88	0,42	8	0,31	13,6	0,95	0,12
Krk	M	62,7	29,7	9,46	6,56	3,25	141	3,20	95,0	7,50	1,05
	SD	3,72	1,83	1,1	0,41	0,35	18	0,28	9,90	1,30	0,1
Labin	M	51,4	26,2	10,4	6,64	3,16	111	3,27	86,2	6,34	0,99
	SD	4,57	2,6	1,16	0,86	0,33	15	0,25	22,1	0,92	0,12
Šipovo	M	51,9	26,3	9,68	7,05	3,29	109	3,28	78,6	6,08	1,04
	SD	5,42	2,68	1,27	1,24	0,56	19	0,44	22,1	1,02	0,17
Vrhovine	M	56,5	26,8	10,4	7,70	3,51	105	3,4	92,1	6,77	1,11
	SD	8,56	3,05	1,44	1,28	0,57	17	0,46	17,9	1,07	0,13

Tablice 6 i Slike 1 vidljivo je da prva glavna sastavnica objašnjava 43,2 % ukupne varijabilnosti, dok druga glavna sastavnica objašnjava 21,0 % ukupne varijabilnosti. Prva glavna sastavnica u visoko je negativnoj korelaciji s pet morfoloških svojstava, a to su: udaljenost od sredine grbice do vrha štitića (DAU), visina štitića (AH), širina štitića (AW), debljina štitića (AT) i dužina iglice (NL). Druga glavna sastavnica je u negativnoj korelaciji s dva svojstva, a to su: broj sjemenskih ljusaka (NS) i širina češera (CW).

Tablica 5. Rezultati korelacijske analize između mjerenih morfoloških svojstava češera i iglica crnog bora. Morfološka svojstva: CL–dužina češera; CW–širina češera; AW–širina štitića; AH–visina štitića; DAU–udaljenost od sredine grbice do vrha štitića; NS–broj sjemenih ljusaka; AT–debljina štitića; NL–dužina iglice; NSL–dužina rukavca; NW–širina iglice. n.s. – nije statistički značajno; * – 0,01 $< p <$ 0,05; ** – 0,001 $< p <$ 0,01; *** – $p <$ 0,001.

Table 5 The results of correlation analysis between measured cone and needle morphological characters. Morphological traits: CL–cone length; CW–cone width; AW–width of cone scale apophysis; AH–height of cone scale apophysis; DAU–distance between umbo and scale top; NS–number of cone scales; AT–thickness of cone scale apophysis; NL–needle length; NSL–basal sheath length; NW–needle width. n.s. – not significant; * – 0.01 $< p <$ 0.05; ** – 0.001 $< p <$ 0.01; *** – $p <$ 0.001.

	CL	CW	AW	AH	DAU	NS	AT	NL	NSL	NW
CL		***	***	***	***	n.s.	n.s.	***	***	n.s.
CW	0,502		***	n.s.	*	*	***	***	***	*
AW	0,680	0,542		***	***	n.s.	***	***	**	n.s.
AH	0,456	0,164	0,624		***	***	***	***	*	*
DAU	0,436	0,231	0,591	0,921		***	***	***	**	**
NS	0,183	0,229	-0,182	-0,509	-0,441		n.s.	*	n.s.	n.s.
AT	0,150	0,373	0,395	0,507	0,503	-0,101		n.s.	n.s.	n.s.
NL	0,449	0,431	0,491	0,432	0,433	-0,230	0,123		***	***
NSL	0,447	0,497	0,330	0,263	0,299	0,049	0,185	0,577		***
NW	0,212	0,240	0,210	0,243	0,306	-0,179	0,115	0,615	0,417	

Analiza pomoću molekularnih biljega - *Analysis with molecular markers*

Genetska identifikacija (genotipizacija) klonova u plantaži - *Genetic identification of clones in the clonal seed orchard*

Genotipizacijom svih rameta ustanovljeno je da 37 od ukupno 136 uzoraka ne odgovara navedenom klonu u nacrtu plantaže, tj. da je u plantaži pogrešno označeno 27,2 % rameta. Tri pogrešno označene ramete su po svom genotipu pridružene drugim klonovima, a preostala 34 pogrešno označena uzorka nisu pripala niti jednom klonu i imali su međusobno različite genotipove. Od deset jedinki u kojih su uzorkovane dvije grane zbog niske rašlje sedam je na obje grane imalo isti genotip koji je pripadao odgovarajućem klonu. Jedna jedinka imala je na obje grane isti genotip, ali nije pripadala klonu po nacrtu, a dvije su imale različite genotipove na dvije grane, od kojih je jedan pripadao odgovarajućem klonu. Nacrt plantaže s unesenim promjenama prikazan je na Slici 2.

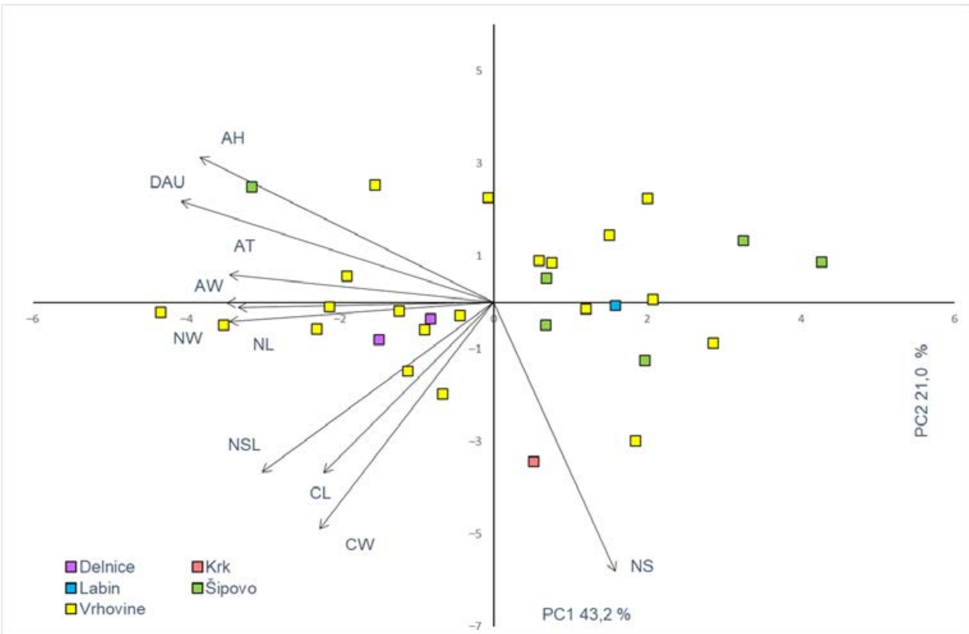
Raznolikost mikrosatelitskih biljega - *Microsatellite markers diversity*

U Tablici 7 prikazani su parametri mikrosatelitskih biljega. Najveći broj alela i informacijski sadržaj polimorfizma imali su biljezi PtTx3020 i PtTx3013. Od polimorfnih alela najmanji broj imao je biljeg SPAC12.5. Sve skupa za svih pet biljega nađeno je 39 alela.

Tablica 6. Pearsonovi korelacijski koeficijenti između 10 morfoloških svojstava češera i iglica i prve četiri glavne sastavnice. Morfološka svojstva: CL–dužina češera; CW–širina češera; AW–širina štitića; AH–visina štitića; DAU–udaljenost od sredine grbice do vrha štitića; NS–broj sjemenih ljusaka; AT–debljina štitića; NL–dužina iglice; NSL–dužina rukavca; NW–širina iglice.

Table 6 Pearson's correlation coefficients between 10 morphological traits of cones and needles and the first four principal components. Morphological traits: CL–cone length; CW–cone width; AW–width of cone scale apophysis; AH–height of cone scale apophysis; DAU–distance between umbo and scale top; NS–number of cone scales; AT–thickness of cone scale apophysis; NL–needle length; NSL–basal sheath length; NW–needle width.

Svojstvo *Trait*	PC–glavna sastavnica *PC–Principal Component*			
	PC1	PC2	PC3	PC4
CL	-0,462	-0,534	-0,557	0,279
CW	-0,472	-0,711	-0,063	-0,142
AW	-0,724	0,000	-0,417	0,316
AH	-0,797	0,456	-0,273	-0,061
DAU	-0,847	0,317	-0,205	-0,158
NS	0,329	-0,842	-0,118	-0,274
AT	-0,716	0,087	-0,061	-0,598
NL	-0,716	-0,060	0,522	0,363
NSL	-0,627	-0,533	0,389	0,059
NW	-0,692	-0,015	0,531	-0,097
Svojstvena vrijednost *Eigenvalue*	4,32	2,10	1,33	0,80
Varijanca (%) *Variance (%)*	43,2	21,0	13,3	8,0
Kumulativna varijanca (%) *Cumulative Variance (%)*	43,2	64,2	77,5	85,5



Slika 1. Dijagram analize glavnih sastavnica na temelju 10 morfoloških svojstava češera i iglica. Morfološka svojstva: CL–dužina češera; CW–širina češera; AW–širina štitića; AH–visina štitića; DAU–udaljenost od sredine grbice do vrha štitića; NS–broj sjemenih ljusaka; AT–debljina štitića; NL–dužina iglice; NSL–dužina rukavca; NW–širina iglice.

Figure 1 Diagram of PCA analysis based on 10 morphological traits of cones and needles. Morphological traits: CL–cone length; CW–cone width; AW–width of cone scale apophysis; AH–height of cone scale apophysis; DAU–distance between umbo and scale top; NS–number of cone scales; AT–thickness of cone scale apophysis; NL–needle length; NSL–basal sheath length; NW–needle width.

Kombinirani PI (probability of identity) za svih pet biljega bio je 0,00005339.

Raznolikost genotipova klonova u klonskoj sjemenskoj plantaži - ***Genetic diversity of clones in the clonal seed orchard***

Prosječni broj alela (N_a) u plantaži bio je 7,6, primijećena heterozigotnost (H_O) iznosila je 0,613, a očekivana heterozigotnost (H_E) 0,646. Koeficijent inbreedinga (F_{IS}) bio je 0,064. Na Slici 3 prikazano je nezakorijenjeno Neighbor-joining stablo izrađeno na temelju udjela zajedničkih alela (proportion of shared alleles, PSA).

RASPRAVA
DISCUSSION

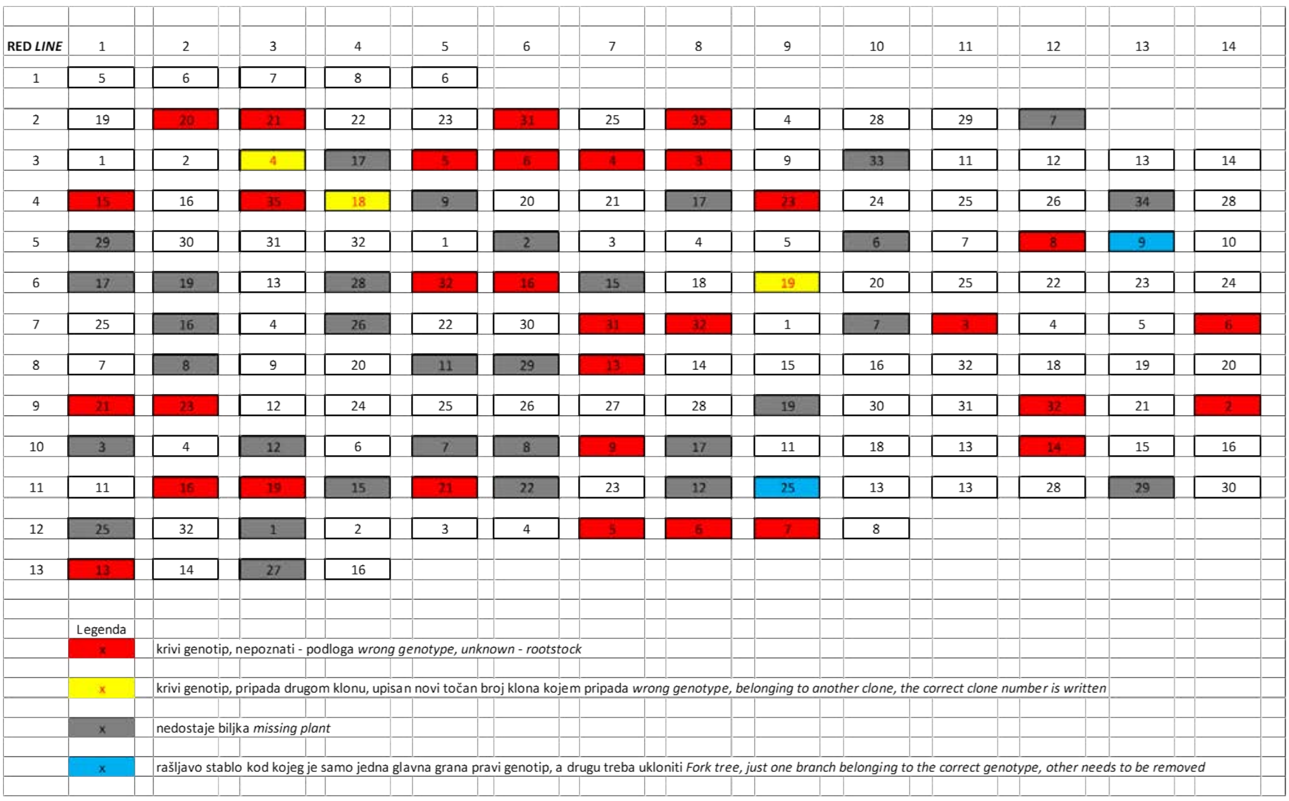
Provedenim istraživanjem utvrđena je velika morfološka varijabilnost iglica i češera crnog bora u klonskoj sjemenskoj plantaži na otoku Krku. Rezultati su pokazali da se klonovi i izvorne populacije mogu razlikovati za sva istraživana morfološka svojstva. Pet podvrsta crnog bora tradicionalno je prepoznato na temelju morfoloških i molekularnih razlika (Vidaković 1957, Liber 2000, Idžojtić 2001, Liber i dr. 2003, Bogunić i dr. 2007, Scotti-Saintagne i dr. 2019) koje su geografski odvojene i prilagođene različitim klimatskim uvjetima. Od ukupnog broja podvrsta, u Hrvatskoj prirodno rastu dvije, subsp. *nigra* i subsp. *dalmatica*, a vrijednosti za dimenzije iglica i češera dobivene u ovom istraživanju odgovaraju vrijednostima koje se navode u dendrološkoj literaturi za tipsku podvrstu (Vidaković 1993, Liber 2000). Navedena podvrsta prilagođena je stanišnim uvjetima submediteranskog područja, pa je korištenje genetski oplemenjenog materijala iz klonske sjemenske plantaže Krk za proizvodnju sjemenskog materijala i sadnica za pošumljavanje tih područja opravdano i optimalno.

Klonske sjemenske plantaže objedinjuju dva ključna cilja: proizvodnju genetski oplemenjenog materijala i *ex-situ* očuvanje genetske raznolikosti ciljne vrste. Ciljevi oplemenjivanja postižu se odabirom fenotipski superiornih jedinki za svojstva od interesa, njihovim vegetativnim umnožavanjem (najčešće cijepljenjem kod šumskog

Tablica 7. Raspon alela, broj alela (N_a), informacijski sadržaj polimorfizma (PIC), vjerojatnost jednakosti – očekivanje učestalosti jednakih parova genotipova u analiziranoj populaciji (probability of identity; PI).
Table 7 Allele range, number of Alleles (N_a), polymorphism information content (PIC), probability of identity; PI - expectation of frequency of equal pairs of genotypes in the analysed population.

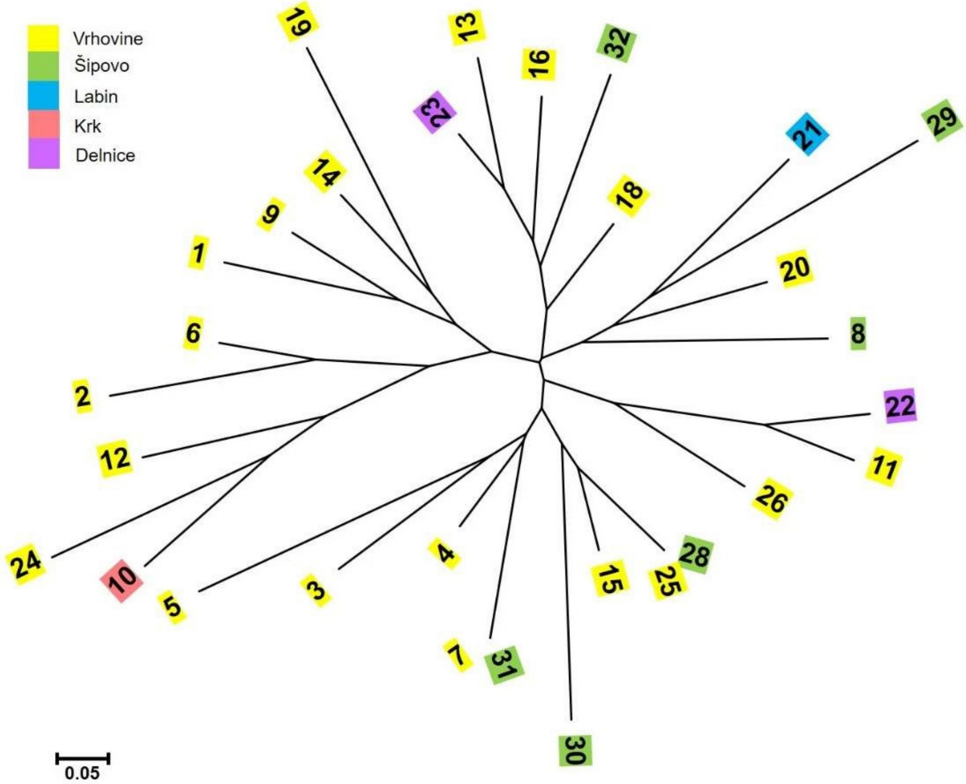
Biljeg *Marker*	Raspon alela *Allele range*	N_a	PIC	PI
PtTx3107	259-283	6	0,404	0,349
PtTx3013	114-158	11	**0,700**	0,099
PtTx3020	84-109	13	**0,851**	0,030
PtTx3049	203-213	5	0,588	0,185
SPAC12,5	252-260	4	0,477	0,274
				0,00005339*

podebljano – PIC > 0,7, visoko informativni biljeg / *bold PIC > 0.7, highly informative marker*
*kombinirano za svih pet biljega / **all five markers combine*



Slika 2. Nacrt plantaže nakon provedenih DNA analiza.
Figure 2 Orchard plan after DNA analysis.

drveća) te njihovim međusobnim razmnožavanjem radi proizvodnje potomstva s očekivanom genetskom dobiti za ciljana svojstva. Ukoliko se u plantažama proizvodi reprodukcijski materijal za unošenje u prirodne sastojine, a ne samo za brzu plantažnu proizvodnju drvne mase, od velike važnosti je genetska raznolikost početnog materijala unesenog u plantažu. Plantaža kao reprodukcijska populacija mora imati dovoljnu genetsku raznolikost kako bi genetska baza za proizvodnju potomstva omogućila prilagodljivost potomstva promjenjivim uvjetima okoliša i otpornost na štetnike.



Slika 3. Nezakorijenjeno Neighbor–Joining stablo izrađeno na temelju udjela zajedničkih alela (proportion of shared alleles, PSA).
Figure 3 Unrooted Neighbour-Joining tree based on the proportion of shared alleles (proportion of shared alleles, PSA).

U tom je procesu ključno osigurati da vegetativne kopije odabranih jedinki budu pouzdano uključene u plantažu kako bi se moglo garantirati porijeklo reprodukcijskog materijala, bilo za primjenu u operativnom šumarstvu ili za daljnje cikluse oplemenjivanja, poput postavljanja klonskih testova. U postupku osnivanja i popunjavanja plantaža postoji mnogo koraka u kojima može doći do grešaka. Prilikom sabiranja plemki s plus stabala (orteta) može se dogoditi pogrešno označavanje. U rasadnicima, tijekom cijepljenja, mogu nastati pogreške u označavanju, a moguće su i situacije poput odumiranja plemke, nakon čega podloga nastavlja rasti, što se može pogrešno interpretirati kao razvoj cijepa. Pogreške se mogu pojaviti i tijekom transporta i sadnje biljaka u plantažu. Nadalje, može se dogoditi nezapaženo preuzimanje podloge te odumiranje plemke nakon što su biljke već posađene na terenu, što dodatno komplicira situaciju.

Ako je moguće, u slučaju kada plantaže nisu prevelike, poželjno je genotipizirati biljke kako bi se ustanovilo jesu li neke od tih grešaka rezultirale pogrešno označenim rasporedom na nacrtu, koji dovodi do daljnjih grešaka, s obzirom na to da se plemke za nadopunu plantaže skupljaju u samoj plantaži, a ne više na izvornom plus stablu. Ako se plemke skupljaju s pogrešne ramete, to dovodi do daljnjeg širenja grešaka, a u slučaju postavljanja genetičkog testa do potpuno nepouzdanih rezultata izmjera u testu.

U ovom istraživanju genotipizirane su sve jedinke (ramete) u plantaži crnog bora i ustanovljeno je da je čak 27,2 % rameta krivo označeno, tj. da ne pripadaju klonu s nacrta. Samo su tri krivo svrstane jedinke zapravo bile pripadnice drugog klona, što možemo pripisati grešci označavanja u nekoj od faza od uzimanja plemke do sadnje. Ostale 34 jedinke imale su različite genotipove koji ne pripadaju ni jednom klonu. Razlog za to može biti greška označavanja u rasadniku, ali vjerojatnije je da je na tim jedinkama došlo do odumiranja plemke i da su te jedinke zapravo stabalca izrasla iz podloge. U slučaju nekih nisko rašljavih stabala došlo je do situacije da je jedna glavna grana porijeklom iz podloge, dok je druga izrasla iz plemke. U takvim slučajevima potrebno je odstraniti granu iz podloge kako bi preostali genotip zaista predstavljao selekcionirani klon.

Nacrt plantaže potrebno je ispraviti tako da se ramete pripisane pogrešnom klonu označe kao klon kojem zaista pripadaju. Sve jedinke nepoznatog porijekla i genotipa potrebno je ukloniti iz plantaže, a buduće plemke za nadopunjavanje plantaže trebaju se uzimati isključivo sa sada potvrđenih rameta. Genetska raznolikost klonova u plantaži, izražena kao očekivana heterozigotnost (H_E), iznosila je 0,646, što je približno vrijednostima koje su u prirodnim populacijama utvrdili Giovannelli i dr. (2017) i Dias i dr. (2020). Neighbor-joining stablo nije pokazalo jasno grupiranje prema izvornim populacijama, osim što su se na jednu granu (lijevu) uglavnom grupirali klonovi iz gospodarske jedinice (GJ) Vrhovine, koji značajno prevladavaju u plantaži. Na istu granu svrstao se i jedini klon s Krka. Klonovi iz ostalih područja bili su raspoređeni po drugim granama, zajedno s ostalim klonovima iz GJ Vrhovine. Provedenom morfometrijskom analizom također nije utvrđeno grupiranje stabala prema pripadnosti izvornim populacijama. Bez obzira na zabilježenu veliku morfološku i genetsku varijabilnost unutar klonske sjemenske plantaže, preporučuje se povećanje genetske baze selekcijom dodatnih plus stabala i uključivanjem klonova iz novih populacija, posebno iz područja u kojem se plantaža nalazi. Naime, većina klonova u plantaži potječe iz jedne populacije, uz male primjese drugih, što naglašava potrebu za daljnjim proširenjem genetske raznolikosti.

ZAKLJUČCI

CONCLUSIONS

- Provedenim istraživanjem utvrđeno je da se klonovi i izvorne populacije na osnovi morfologije iglica i češera statistički značajno razlikuju.
- Dimenzije iglica i češera ukazuju na to da klonovi u istraživanoj sjemenskoj plantaži pripadaju tipskoj podvrsti crnog bora.
- U klonskoj sjemenskoj plantaži pogrešno je označeno 27,2 % jedinki (rameta). Tri su svrstane pod druge klonove kojima zaista pripadaju, dok su ostale imale nepoznate genotipe, vjerojatno potekle iz podloge. Sve takve jedinke potrebno je odstraniti iz plantaže i zamijeniti pravim rametama klona prema nacrtu.
- Kod primjeraka s niskom rašljom, gdje su dvije grane imale različite genotipove, od kojih samo jedan pripada klonu po nacrtu, potrebno je odstraniti granu s nepripadajućim genotipom jer je potekla iz podloge.
- Klonovi u plantaži potječu iz vrlo ograničenog broja populacija, od kojih su neke slabo zastupljene.
- Preporučuje se proširenje genetske baze novoselekcioniranim klonovima.
- Multivarijatnim statističkim metodama nije utvrđeno grupiranje klonova na temelju njihove pripadnosti izvornim populacijama.

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SUMMARY

The aim of this study was to assess the genetic diversity of clones within the clonal seed orchard of black pine (*Pinus nigra* J.F.Arnold, Pinaceae) located in the area of the Krk Forest Office, using morphological and molecular markers, and to conduct genetic identification (genotyping) of ramets to verify the accuracy of the orchard layout. The study included samples from 136 ramets across five populations. Microsatellite markers were used for the genotyping of clones, and morphometric analysis was carried out based on ten morphological traits of needles and cones. Significant differences were observed among clones and populations for all morphological traits examined. The average needle length was 89.8 mm, and the cones, averaging 55.7 mm in length and 26.8 mm in width, contained 106 seed scales. The orchard layout revealed 27.2% of mislabeled ramets, of which three belonged to different clones, while others had unknown genotypes. Main sources of error included scion die-off and growth of rootstock shoots, with labeling errors also being a possibility. Corrective actions should include proper labeling of misidentified ramets and the removal of individuals with unknown origins or genotypes. Future scions for orchard supplementation should be sourced exclusively from confirmed ramets. For specimens with branching discrepancies (where different genotypes were identified on two branches, one matching the designated clone), the incorrect branch must be removed as it originates from the rootstock. Comparisons with other studies on black pine using microsatellite markers indicate that the genetic diversity in the orchard (H_E = 0.646) aligns with values found in natural populations. Since most clones originate from a limited number of populations, with some poorly represented, expanding the genetic base with newly selected clones is recommended if the orchard is to be maintained. Multivariate statistical methods did not reveal grouping of clones based on their original population affiliations. The results of this study hold practical value for forestry as seed orchards serve as a suitable base for *ex situ* conservation of genetic diversity and the production of genetically superior seeds for stand restoration or natural regeneration support. The findings also highlight the importance of accurate clone labeling to avoid negative consequences in managing clonal seed orchards.

KEY WORDS: black pine, morphometric analysis, genetic analysis, microsatellites, clonal seed orchard, gene conservation

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FIRST REPORT OF *Diaporthe eres* ASSOCIATED WITH STEM AND BRANCH CANKER ON *Quercus robur* L. IN CROATIA

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SUMMARY

In June 2020, stem and branch cankers were observed on young *Quercus robur* trees growing in a floodplain forest near the Sava River in the eastern part of Croatia. Samples of affected stems and branches were randomly collected, and fungi present in the symptomatic tissue were isolated on agar media. The molecular and morphological identification of the obtained cultures revealed 29 fungal isolates belonging to 12 different taxa. The most frequently isolated species was *Diaporthe eres*, found in 77% of sampled trees. The ability of *D. eres* to cause cankers was tested in a pathogenicity trial on 3-year-old *Q. robur* saplings. Bark and wood necroses developed on all inoculated saplings, and *D. eres* was successfully re-isolated and identified using molecular tools. None of the control saplings revealed any symptoms during the trial. Therefore, Koch's postulates were fulfilled, and *D. eres* was verified as a causative agent of cankers on *Q. robur*.

KEY WORDS: pedunculate oak, bark necrosis, wood necrosis, pathogenicity, Sava River

INTRODUCTION

Quercus robur L. (pedunculate oak) is a widespread European tree species, growing in forest ecosystems and urban areas, where it provides multiple economic, social, and ecological benefits (Eaton et al. 2016, Mölder et al. 2019). In Croatia, it is the second most abundant forest tree species, covering approximately 15% of the total forest area (350 000 ha), mostly in lowland and floodplain regions, where it is greatly valued for its ecological services and high-quality timber (Županić et al. 2009, Čavlović 2010). Unfortunately, the decline of this valuable tree species has been reported in several European countries during the last few decades, caused by the synergistic activity of different abiotic and biotic factors (Thomas et al. 2002). Since *Q. robur* has shown to be highly susceptible to changes in water availability and climate changes, these factors are considered to be crucial or at least very important drivers for its decline (Ugarković et al. 2016, Macháčová et al. 2022). Besides a direct impact on the species, the aforementioned changes can also lead to a proliferation of weak and opportunistic pathogens, such as different endophytic and saprobic fungi, otherwise harmless organisms which are present

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in the healthy plant tissue or are widespread in the environment (Marçais and Breda 2006, Macháčová et al. 2022).

During June 2020, stem and branch cankers were observed on young *Q. robur* trees growing in a floodplain forest near the Sava River in the eastern part of Croatia. It was hypothesized that fungal pathogens might have caused these symptoms. To test this hypothesis, the following aims were set in this research: (1) to isolate and identify fungi present in the necrotic tissue, and (2) to test the pathogenicity of the most frequently isolated fungal species on *Q. robur* saplings.

MATERIALS AND METHODS

Study area and recorded symptoms

Reddish brown sunken canker lesions and associated chlorosis of leaves were observed during June 2020 on stems and branches of young *Q. robur* trees in the natural six-year-old floodplain forest stand in the Sava River basin in Croatia (44°55'09.4"N, 18°50'08.1"E). The forest stand was established by natural regeneration. Approximately 10% of *Q. robur* trees throughout the entire forest stand area (66.36 ha) were affected. On the less affected trees, cankers were observed only on the branches in the crown, and on the more affected trees, canker lesions have spread from branches to the stem. Necrotic bark was sunken in comparison to adjacent healthy tissue and reddish-brown to black in colour. Phloem, cambium, and xylem (sapwood) underneath the cankers were darkly discoloured and necrotic as well. Leaves on the affected branches displayed chlorosis and wilting and were shed prematurely (Figure 1).

Fungal isolation and identification

Samples of affected stems and branches were randomly collected from 13 trees in July 2020 (1 branch or stem per tree, 13 samples in total). Fungal isolations were made from the edges of symptomatic stem and branch bark (phloem) and wood (xylem) tissue. After the surface sterilization for 1 min in 96% ethanol, followed by a rinse in sterile distilled water, four small pieces of tissue (5 x 5 mm) per sample were plated on potato dextrose agar (PDA, Oxoid) supplemented with streptomycin sulphate (200 mg/L, Sigma-Aldrich) in 90 mm Petri dishes. The Petri dishes were then incubated in the dark at 19–20°C for one month and emerging mycelia were subcultured onto PDA. The obtained pure fungal cultures were grouped into morphotypes according to their morphological characteristics. At least one mycelial culture from each morphotype was subjected to molecular identification.

DNA was extracted from mycelia cultured in malt extract broth (MEB, Liofilchem) in 2 ml microtubes for 7 days by the salting-out method according to Cenis (1992). Minor modifications were made to this method according to Kranjec Orlović et al. (2024). The internal transcribed spacer (ITS) region of the ribosomal DNA (rDNA) was amplified in polymerase chain reaction (PCR) with primers ITS1-F (Gardes and Bruns 1993) and ITS 4 (White et al. 1990), according to the established protocol (Kranjec Orlović et al. 2021). For two isolates belonging to the genus *Diaporthe* (QUE15 and QUE17), the partial translation elongation factor 1-α (TEF1- α), calmodulin (CAL) and β-tubulin (TUB) genes of the isolates were additionally amplified using the primers EF1-728F/EF1-986R, CAL-228F/CAL-737R (Carbone and Kohn 1999), and Bt2a/Bt2b (Glass and Donaldson 1995), following the protocols of Udayanga et al. (2014). The obtained PCR products were sequenced in both directions with primers used for amplification at the DNA sequencing facility of Macrogen Europe (Amsterdam, Netherlands). The obtained raw sequences were edited using BioEdit

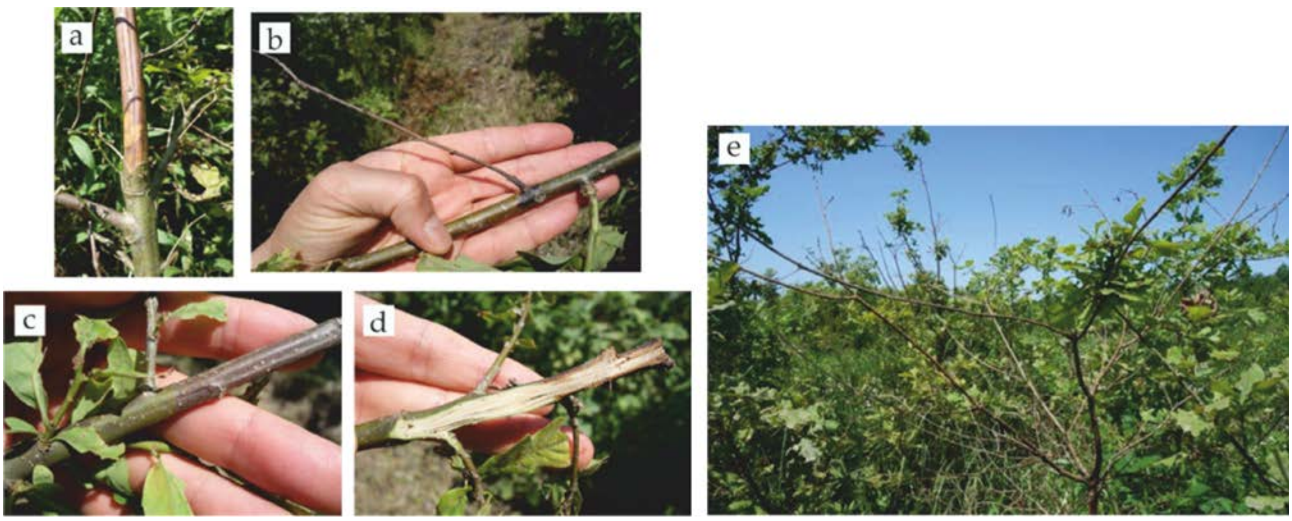

Figure 1 Symptoms observed on *Q. robur* trees: (a–c) reddish brown to black sunken canker lesions on stem and branches; (d) discoloration and necrosis of phloem, cambium, and xylem (sapwood) underneath the cankers; (e) premature shedding of leaves on affected branches.

Sequence Alignment Editor v.7.2.5 software (Hall 1999) and then compared with reference sequences deposited in the National Center for Biotechnology Information (NCBI) GenBank using the Basic Local Alignment Search Tool (BLAST + 2.15.0) (Altschul et al. 1990). Sequences with 99.0%–100% and 95.0%–98.99% similarity to the reference ones were identified to the species level and to the genus level, respectively. Morphological characteristics of the obtained cultures grown on PDA for 30 days were used to confirm the results of molecular identification. Spores were harvested from pycnidia which developed in cultures, and were visualised using the Olympus DP-23 camera mounted on a microscope (Olympus BX-41). The spores were measured using the associated PRECiV Core software (Olympus, version 2.1) and their shape and dimensions were compared to the description of *D. eres* in Udayanga et al. (2014). In total, 100 spores were measured (length and width).

Pathogenicity test

Pathogenicity of the most frequently isolated fungus in this research, *Diaporthe eres* Nitschke, was tested on 3-year-old *Q. robur* saplings grown in a ground in an open field trial conducted in the nursery "Šumski vrt i arboretum" located at the University of Zagreb Faculty of Forestry and Wood Technology (45.8202° N, 16.0228° E). Saplings were on average 182 cm (± 22 cm) high and with an average root collar diameter of 1.8 cm (± 0.3 cm). During the experiment, which was conducted from 24 May to 5 July 2021, an average daily temperature ranged from 10 to 30°C (10–20°C in May, 15–30°C in June and 20–27°C in July), and total monthly rainfall amounted to 124 mm, 13.2 mm and 74.5 mm in May, June and July, respectively. Ten saplings were inoculated with the *D. eres* isolate QUE15. The upper part of a stem (30 cm from the top) was surface disinfected with 96% ethanol and then a small piece of outer bark (7 mm × 7 mm) was cut with a sterile scalpel. A PDA-mycelium plug was taken from the margin of a seven-day-old culture with a sterile steel cork borer (inner diameter 7 mm). The plug was placed in an inflicted wound (mycelium facing the inner bark), the cut bark was re-attached on top of the plug, and the stem was wrapped with Parafilm (Bemis Company Inc.) and with a piece of aluminium foil. Ten saplings were used as controls and inoculated with a sterile PDA plug applied as described above. The saplings were checked for symptoms on the outer bark around the inoculation point weekly. The re-isolation of *D. eres* was attempted six weeks after the inoculation. Stem sections 5–8 cm long with an inoculation point were submerged into 0.5% sodium hypochlorite for 15 seconds, 96% ethanol for one minute, rinsed in sterile distilled water and dried under the laminar flow hood, before transferring five pieces of inner bark or xylem (5 mm × 5 mm) taken around the margin of the observed necroses onto PDA. The obtained isolates which morphologically belonged to the genus *Diaporthe* were subjected to identification by molecular analysis of ITS region of DNA, using the already described protocol (one representative mycelial culture per inoculated sapling).

RESULTS

Fungi isolated from stem and branch cankers on *Q. robur*

In total, 29 fungal isolates belonging to 12 different taxa (Table 1) were obtained from 52 plated pieces of tissue taken from the affected *Q. robur* in the Sava River basin (four pieces from each of the 13 sampled trees).

Table 1 Parameters of multiple linear regression model for productivity.

Phylum	Fungal taxon	GenBank accession no. [1]	Isolation frequency (% of colonized samples)
Ascomycota	*Diaporthe eres* Nitschke	PQ475913 / 497657 / 497661 / 497659 PQ475914 / 497658 / 497662 / 497660	77
	Neocucurbitaria sp.	PP496181	23
	Dendrostoma leiphaemia (Fr.) Senan. & K.D. Hyde	PP496182	15
	Monochaetia sp.	PP496183	15
	Alternaria sp. 1	PP496184	8
	Alternaria sp. 2	PP496185	8
	Cladosporium cladosporioides (Fresen.) G.A. de Vries	PP496186	8
	Didymellaceae sp.	PP496187	8
	Paraconiothyrium brasiliense Verkley	PP496188	8
	Paraphaeosphaeria sp.	PP496189	8
	Sordaria fimicola (Roberge ex Desm.) Ces. & De Not.	PP496190	8
	Valsa ceratophora Tul. & C. Tul.	PP496191	8

[1] For two *D. eres* isolates (QUE15 and QUE17), GenBank accession numbers are provided for the ITS, TEF, CAL and TUB DNA region, respectively, and for other isolates only for the ITS region.

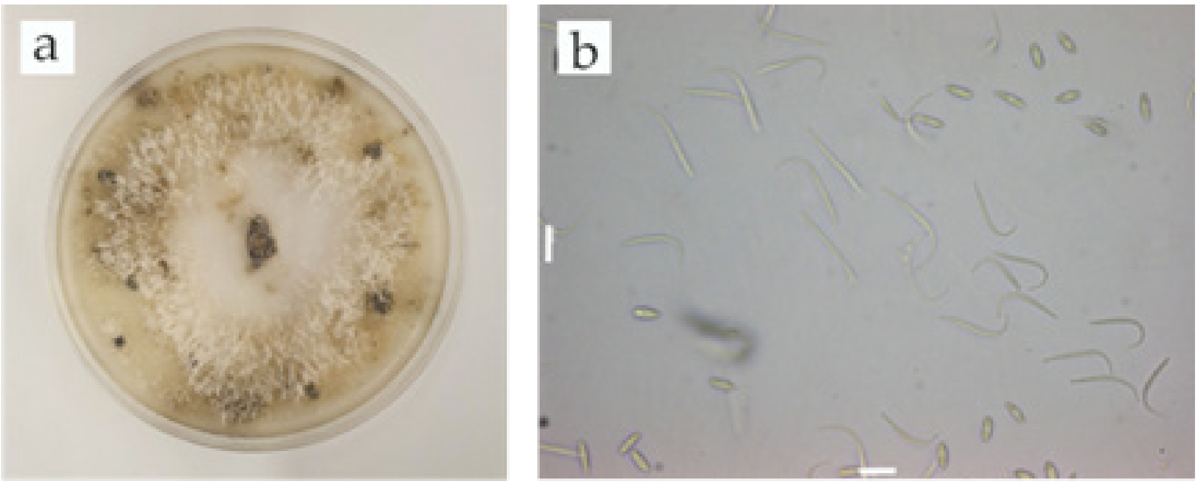

Figure 2 Morphological characteristics of *D. eres* isolate QUE15: (a) mycelium culture on PDA at 21°C after 30 days, (b) alpha and beta conidia, white scale bars: 10 μm.

The most frequently isolated species was *D. eres*, isolated from 77% of samples. Pure cultures consisted of white aerial mycelium, which turned gray after 3–4 weeks and produced dark pycnidia. Alpha conidia were hyaline, aseptate, biguttulate, fusiform to ellipsoid, measuring 5.7 to 7.9 × 2.3 to 3.5 µm (n = 50). Beta conidia were hyaline, aseptate, linear to curved, measuring 17.2 to 29.7 × 0.9 to 2.4 µm (n = 50) (Figure 2). BLAST searches confirmed isolates QUE15 and QUE17 as *D. eres*, showing the similarity of both with the *D. eres* CBS 101742 (GenBank accession numbers: KC343073/KC343799/KC343315/KC344041). QUE15 had 100% (549/549 nt), 100% (342/342 nt), 99.74% (389/390 nt) and 99.82% (549/550 nt) homology, whereas QUE17 had 100% (549/549 nt), 99.42% (342/344 nt), 99.23% (388/391 nt) and 99.82% (552/553 nt) homology with *D. eres* CBS 101742, for ITS, TEF, CAL and TUB region, respectively.

Pathogenicity of *D. eres* on *Q. robur* saplings

The first symptoms on inoculated saplings appeared one week after the inoculation, in the form of bark discoloration extending only few millimetres around the inoculation point. During the next few weeks bark discoloration extended further around the inoculation point and became darker in colour, indicating tissue necrosis. Six weeks after the inoculation, brown to black necroses extending 2–3 cm around the inoculation point were visible. Slight cracking of the bark was observed on some saplings (Figure 3a). Bark removal revealed that these necroses extended into sapwood, and only in a few cases into the heartwood as well (Figures 3b to 3d). In control saplings, callus was formed around the inoculation point and there were not any visible discolorations or necroses on bark or wood (Figures 3e and 3f).

Mycelia cultures morphologically resembling the genus *Diaporthe* were isolated from all ten inoculated saplings. ITS analysis confirmed that these isolates share 100% identity with the *D. eres* isolate QUE15. Their sequences were uploaded into the NCBI GenBank online database (accession numbers: PQ475915-24). No *Diaporthe* resembling isolates were obtained from the control saplings.

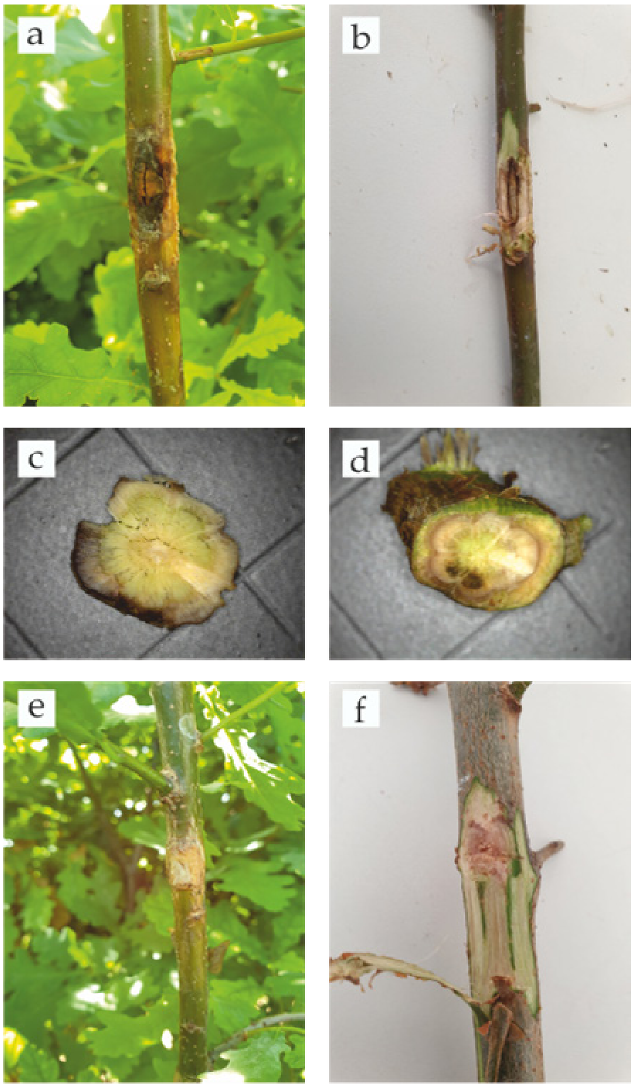

Figure 3 The appearance of *Q. robur* saplings six weeks after the inoculation: (a–d) symptoms on saplings inoculated with *D. eres* isolate QUE15; (e–f) lack of symptoms on control saplings.

DISCUSSION AND CONCLUSIONS

Diaporthe eres was frequently isolated from stem and branch cankers on oak trees from the natural floodplain forest stand in the Sava River basin in 2020, and the ability of the fungus to cause bark and wood necroses on *Q. robur* was confirmed by a pathogenicity test, where Koch's postulates were fulfilled on all inoculated saplings. Most of the other fungal taxa isolated from cankers on *Q. robur* in this study were represented with only one isolate. According to the available literature, some of the identified genera and species have been previously associated with *Q. robur* as endophytes or opportunistic pathogens, such as some members of the genera *Monochaetia* (Gennaro et al. 2003, Akdeniz and Hacer 2023) and *Neocucurbitaria* (Jaklitsch et al. 2018, Costa et al. 2020), and the species *Dendrostoma leiphaemia* (Fr.) Senan. & K.D. Hyde (Jaklitsch and Voglmayr 2019). Due to limited time and resources, *D. eres* was the only species tested for its pathogenicity towards *Q. robur* in this study.

In literature *D. eres* has been described as an opportunistic pathogen which colonizes many woody plant species, causing leaf spots, shoot blight, stem and branch cankers and other various disease symptoms. It was reported on *Juglans cinerea* L. in the USA (Anagnostakis 2007), *Prunus persica* (L.) Batsch in Greece and Italy (Thomidis and Michailides 2009, Prencipe et al. 2017), *Vitis vinifera* L. in the USA (Baumgartner et al. 2013), *Vaccinium* species in Europe (Lombard et al. 2014), *Ziziphus jujuba* Mill. in China (Zhang et al. 2018), *Corylus avellana* L. in the USA (Wiman et al. 2019), *Fraxinus excelsior* L. in Montenegro (Vemić et al. 2019), *Malus domestica* (Suckow) Borkh. in Canada (Ali et al. 2020), *Cinnamomum camphora* (L.) J.Presl in China (Li et al. 2021), *Prunus amygdalus* Batsch (*P. dulcis* (Mill.) D.A.Webb) in the USA (Holland et al. 2021), *Juglans regia* L. in Hungary (Zabiák et al. 2023), and *Prunus avium* L. in China (Chen et al. 2023). In Croatia, the fungus was reported to cause cane blight on *Rubus* sp. (Vrandečić et al. 2011), wood canker of *V. vinifera* (Kaliterna et al. 2012), and twig blight and canker of *Vaccinium corymbosum* L. (Ivić et al. 2018). In this study, necroses obtained in a pathogenicity trial were limited to a relatively small circumference around the inoculation point on stems of *Q. robur* saplings. This is consistent with the results of previous research on oaks, where the fungus was isolated from the wood and bark necroses on *Quercus suber* L. in Portugal and *Q. robur* in Poland and described as a weak pathogen on these hosts based on the relatively small lesion development in inoculation trials (Lopes et al. 2021, Jankowiak et al. 2022). Based on the obtained results in this study, the same conclusion could be drawn.

The endophytic lifestyle of *D. eres* in different plant tissues was also reported by some authors, e.g. in shoots of *Prunus domestica* L. (Abramczyk et al. 2022), branches of *Fagus sylvatica* L. (Kowalski and Kehr 1992), leaves of *Acer macrophyllum* Pursh (Sieber and Dorworth 1994), bark of *Taxus chinensis* (Pilg.) Rehder (Liu et al. 2009), leaves and branches of *Quercus cerris* L. (Moricca et al. 2012), needles of *Larix kaempferi* (Lamb.) Carrière and *Pinus densiflora* Siebold et Zucc. (Kim et al. 2013), and twigs and branches of *Citrus* sp. (Huang et al. 2015). In the light of the above, there is a possibility that the fungus was already present in the healthy wood or bark of *Q. robur* in the studied floodplain forest as an endophyte, and that it shifted to a pathogenic lifestyle and caused cankers on those plants which experienced a loss of vitality due to other factors. Although isolations from healthy control saplings in this study did not corroborate this (no *D. eres* found in the healthy *Q. robur* tissue), isolation of the fungus from the healthy wood or bark tissue of *Q. robur* growing in natural habitats should be attempted in future studies.

The studied *Q. robur* trees with cankers were removed during the usual sanitary activities by foresters (personal communication) and the remaining trees have not exhibited similar symptoms on a larger scale so far (to the day of publishing this article). *Q. robur* in eastern Croatia has shown to be highly susceptible to climate change and availability of water (Ugarković et al. 2016), and it is often exposed to severe attacks by an invasive pest, *Corythuca arcuata* (Say, 1832) (Csóka et al. 2020). It is possible that the young oak trees in this study underwent the loss of vitality caused by some of these factors, and that *D. eres*, and possibly some other fungi, shifted from endophytic to parasitic lifestyle and contributed to the development of cankers. In the case of another outbreak of similar symptoms on oaks in Croatia, the pathogenicity of other fungi and other *D. eres* isolates towards *Q. robur* should be tested in inoculation trials, to verify the results obtained in this study.

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Održan 4. Rika Fest u Delnicama

Tekst/foto: **Marija Glavaš**

Vabljenje rikom tradicionalni je goranski način lova

Po četvrti put za redom, nekih dva tjedna prije nego što će početi prava jelenja rika, u Delnicama je održan Rika Fest, manifestacija tijekom koje se lovci nadmeću u oponašanju rike jelena. Bogati program sadržavao je i natjecanje u spravljanju lovačkog kotlića i reviju lovačkih pasa.

Oponašanje rike jelena može zvučati smiješno, ali zapravo zahtijeva znanje i uvježbano uho jer treba moći prepoznati različite zvukove i znati koja je svrha kojeg. Kada se tome doda motivacija i umijeće, imamo natjecatelja spremnog za sudjelovanje na Rika Festu, još jednom događanju u Delnicama koje okupi i staro i mlado i gdje se svi dobro zabave. Inicijativa je krenula iz Turističke zajednice Gorskog kotara po uzoru na natjecanja kakva se pod istim kriterijima održavaju po drugim europskim mjestima.

Ovogodišnja manifestacija održana je 30. kolovoza pod okriljem zelenih krošanja na Trgu kralja Tomislava pod pokroviteljstvom lovačkog saveza Hrvatske, Lovačkog saveza Primorsko goranske županije i Grada Delnica. Uz središnje događanje, oponašanje rike jelena, održano je natjecanje u spravljanju najukusnijeg lovačkog kotlića i revija lovačkih pasa.

Svečano otvorenje započelo je hrvatskom himnom i nastupom rogista Hrvatskog lovačkog saveza. Prisutne je potom pozdravio Josip Malnar predsjednik Lovačkog saveza Primorsko - goranske županije. Predsjednik Hrvatskog lovačkog saveza Mato Čičak prisutne je upoznao s Malnarovim prijedlogom o potrebi za uključenjem u europsku asocijaciju kako bi naš državni prvak mogao nastupiti na europskom prvenstvu. Događanja je svečano otvorio gradonačelnik Delnica Igor Pleše.

Za titulu najboljeg imitatora rike jelena tijekom 4. Rika Festa i 3. državnog prvenstva nadmetala su se trinaestorica kandidata među kojima i trojica zaposlenika iz UŠP Delnice. Stručni suradnik za plan i analizu u UŠP Delnice Valter Crnković i upravitelj u Šumariji Klana Matija Laginja natjecali su se za svoja lovačka društva, dok je lovočuvar zaposlen u UŠP Delnice Damir Prokopović rikao za Hrvatske šume.

Svoje imitacijske vještine najprije su pokazala četvorica dječaka i za to bila prigodno nagrađena. Sedmogodišnjeg rikača Vitu Logara s oponašanjem rikanja upoznao je njegov djed Damir Prokopović, pa se može reći kako mališan nastavlja ovu lijepu lovačko – šumarsku tradiciju. Zatim su

Oponašatelj rike

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DIVERSITY OF WOODY PLANTS IN URBAN PARKS OF SKOPJE, NORTH MACEDONIA

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SUMMARY

Urban parks are crucial components of a city's green infrastructure, offering significant benefits from both social and environmental perspectives. They provide many ecosystem services and play a key role in maintaining, preserving, and enhancing urban biodiversity. This paper analyses the woody plant diversity in three urban parks in Skopje, North Macedonia. The research identified 90 different woody plant taxa in the analyzed parks, belonging to 42 genera and 23 families. The parks have a significantly higher number of non-native taxa compared to the native ones, as well as a significantly higher number of deciduous taxa compared to evergreen taxa. Although non-native species dominate to a great extent over the native ones, there is no threat from invasive plant species in the researched parks. Furthermore, the analyses included the calculation of biodiversity indices (alpha indices: Shannon, Simpson, and Berger-Parker, and also Sørensen beta index). The results showed that none of the parks are highly significant from a biodiversity perspective. The alpha indices indicate a low to moderate biodiversity in the studied North Macedonian urban parks. On the other hand, the Sørensen beta index indicated a more positive view, emphasizing the lack of significant similarity among the studied urban parks. Nevertheless, there is a clear need to enhance the biodiversity of woody plants in urban parks in Skopje. Integrating biodiversity considerations into the process of planning, landscape design of urban parks, and their maintenance is crucial. Establishing biodiversity monitoring as a standard practice will be essential for understanding the real situation in urban parks and enabling timely interventions.

KEY WORDS: woody plants, dendroflora, trees and shrubs, diversity, biodiversity indices, horticulture, urban parks

INTRODUCTION

Urban parks are essential components of urban green infrastructure (Breuste et al. 2015). They provide numerous ecosystem services, with biodiversity being one of the most important (Lakičević et al. 2022). These parks serve as specific urban green places, acting as habitats for various flora and fauna, thereby representing significant biodiversity hotspots within cities (Nielsen et al. 2014, Vidaković et al. 2020). As urbanization continues to rise, the fundamental importance of conserving urban biodiversity remains a subject of ongoing debate (Nilon 2011), with growing interest in this area (Cornelis and Hermy 2004, Dearborn and Kark 2010). One of the key methods for preserving biodiversity within urban habitats is monitoring changes in biodiversity over time (Volis 2018, Shilling et al. 2020, Lakičević et al. 2022). This procedure is useful for determining the presence of species, their persistence, or their potential loss from the area.

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The variety of organisms and the measurement of their diversity have long been of interest to ecologists, particularly in natural habitats (Sohrabi and Habashi 2011). Nowadays, the diversity of tree species has also become a popular and interesting research topic for urban foresters and landscape designers (Hilbert et al. 2023). Greater diversity increases the functionality of trees, making their roles in urban environments more significant (Zare et al. 2009). An increase in plant species within man-made urban ecosystems can enhance environmental sustainability (Fard et al. 2015). This understanding of biodiversity allows for timely interventions during the urban planning process. Moreover, trees as dominant landscape elements in many urban areas and parks also influence other aspects of biodiversity. This makes them an important consideration in urban management decisions (Nowak 2010), further highlighting their crucial role in enhancing urban biodiversity (Vidaković et al. 2020).

In the past, analyses showed that biodiversity played a limited role in urban planning, often overshadowed by other priorities (Miller et al. 2009). However, recommendations to focus on challenging and relevant hypotheses, evaluate outcomes, and make knowledge actionable to provide specific guidance, tools, and workflows to increase biodiversity's influence in urban planning (Norton et al. 2016) are becoming more relevant today. Certain studies have found a positive correlation between biodiversity in urban parks and well-being, suggesting that urban planners should prioritize enhancing diversity in urban green spaces (Brown and Grant 2005, Wood et al. 2018). Taylor and Hochuli (2015), in their study on creating better cities, emphasize the importance of considering biodiversity during the design process. They argue that urban designers should recognize the potential of their work to enhance human well-being by integrating biodiversity into their design and research.

In recent years, the diversity of woody plants in urban parks has become an increasingly researched topic (Bo and Zhi-Yi 2003; Cornelis and Hermy 2004; Poljak et al. 2011; Tafra et al. 2012, 2013; Nielsen et al. 2014; Zebec et al. 2014; Sahani and Raghavaswamy 2018; Savosko et al. 2020; Vidaković et al. 2020; Çoban et al. 2021; Öğçe et al. 2022; Zibtseva 2022; Lakičević et al. 2022; Ma et al. 2023). These studies typically analyze various aspects such as the number of species and varieties, the presence of deciduous and evergreen taxa, as well as the presence of woody plants by life form, and the number of native and non-native species. Beyond these common methods of studying and analyzing diversity, biodiversity in an area can also be measured in two distinct ways that include alpha and beta diversity indices (Heip et al. 1998, Gotelli and Colwell 2001, Stirling and Wilsey 2001). The most commonly used indices for determining biological diversity are alpha indices, such as the Shannon index (Shannon 1948), which measures both richness and evenness, and the Simpson index (Simpson 1949), which focuses on evenness. These indices are determined by the number of different taxa and their presence in a given area. Another alpha index that measures evenness is the Berger-Parker index (Berger and Parker 1970), which, in addition to considering the number of different taxa and their distribution, also takes into account the dominance of particular taxa. This makes it quite significant from the perspective of urban planning and landscape design, as dominant taxa influence the design and style of the park (Kümmerling and Müller 2012). Unlike alpha indices, which measure diversity within a single area, beta diversity indices are used to compare biodiversity between different areas or, less frequently, within the same area over different time periods (Legendre 2019, Lakičević et al. 2022). Understanding beta-diversity indices is essential for protecting regional diversity (Socolar et al. 2016) and can directly assist urban planning. This comprehensive approach to studying the diversity of woody plants in urban parks not only provides valuable ecological insights but also supports effective urban planning and landscape design.

Urban parks and urban dendroflora in North Macedonia (Shotaroska et al. 2019, Stipanović et al. 2022, Dimitrova et al. 2023, Stipanović and Andonovski 2024) have rarely been mentioned in research, presenting a significant opportunity for investigation. This study aimed to assess the current state of urban woody plant diversity in three North Macedonian parks and identify potential actions to enhance it. The focus was on preserving and improving biodiversity and enhancing the overall quality of life for urban residents. The specific objectives of this research were: (1) to determine and examine the abundance of woody plant taxa, their family affiliation, and the number of native, non-native, and invasive taxa; and (2) to analyze the diversity of woody plants in the studied parks using various biodiversity indices, including the alpha indices (Shannon, Simpson and Berger-Parker) and the Sørensen beta index.

MATERIALS AND METHODS

Study area

The research was conducted in three urban parks in Skopje, North Macedonia: Macedonia 1 Park, Airplane Park, and Woman-Warrior Park. These parks are all located in the central city area of Skopje, each within a different municipality (Figure 1).

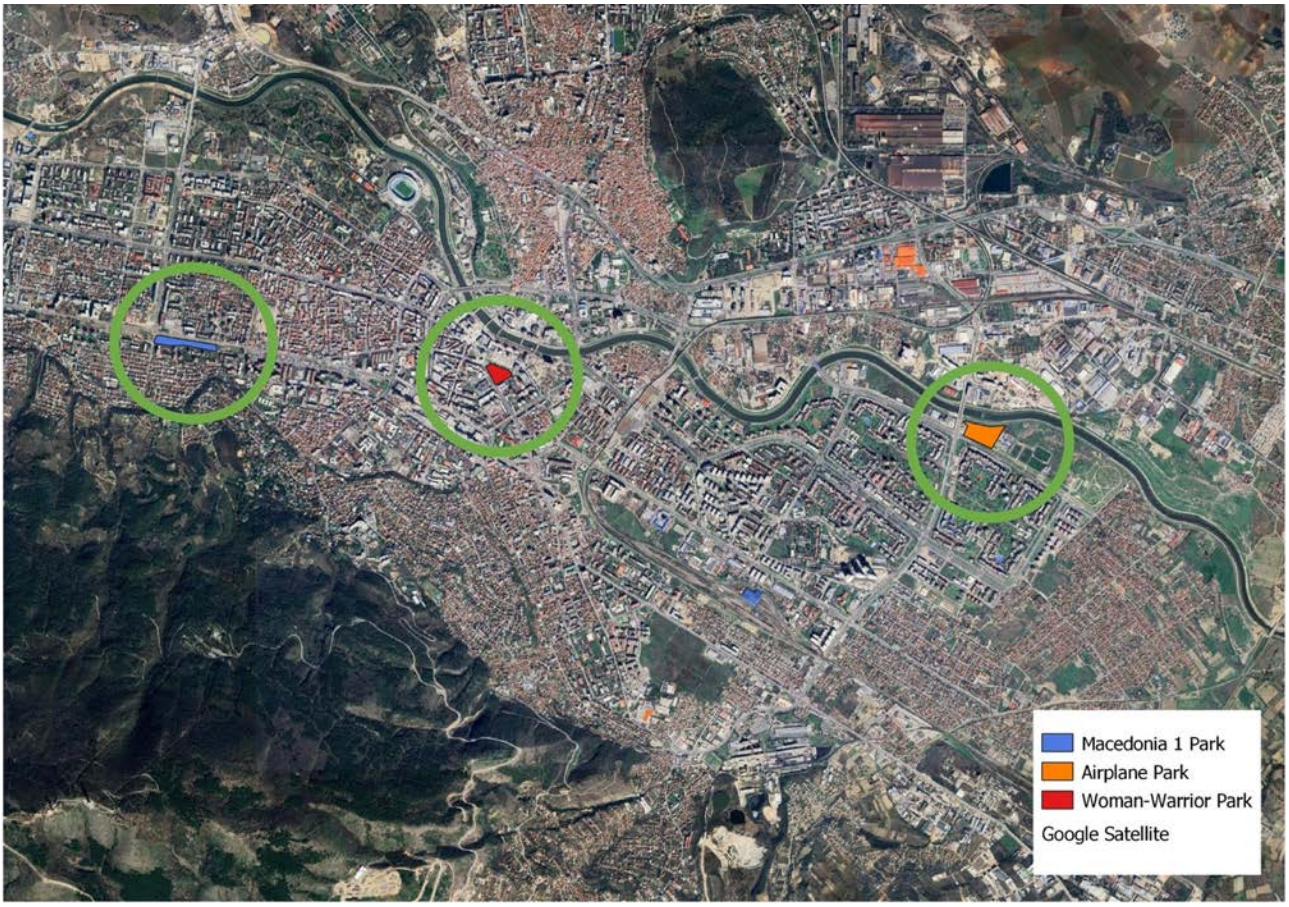

Figure 1 Locations of the analyzed parks in Skopje (North Macedonia).

Macedonia 1 Park is situated in the municipality of Karposh, in the settlement of Kapishtec. It is a linear park, bordered to the north by Metropolit Teodosij Golaganov Boulevard and to the south by Jurij Gagarin Street. Established in 2012, the park has been progressively enhanced over the years with a variety of plantings. This park is multifunctional, comprising various elements or sections, including a recreational area with an outdoor gym and white gravel trim trail, children's play area and a playground, a cycling track for children, space for quiet relaxation, and a dog park. Each section offers a range of activities. Due to its diverse offerings and the densely developed nature of the Kapishtec settlement, along with the scarcity of large parks in the area, Macedonia 1 Park plays a crucial role for the local community.

Airplane Park is located in the municipality of Aerodrom, within the settlement of Novo Lisiche. On one side, it borders the Vardar River, while on the other, it is bordered by ASNOM Boulevard. This park is frequently visited by local residents, primarily due to its location next to the Vardar River quay and the opportunity to enjoy the cherry blossoms during a certain period of the year. Additionally, it offers a variety of recreational options, including a cafeteria, a restaurant, various children's play equipment, and a basketball court.

Woman-Warrior Park is in the municipality of Centar, right in the city center, next to the city's oldest shopping center. Due to its location and, primarily, the shade from the old trees and resting areas, the park is always filled with passers-by who stop to rest.

All selected parks are classified as urban parks. Macedonia 1 Park and Airplane Park are relatively new, created in the previous decade, while Woman-Warrior Park is the oldest, established in the early 1970s (Table 1).

Although the three parks vary in size, they have some similarities in vegetation. Both Macedonia 1 Park and Woman-Warrior Park feature a diverse array of vegetation, including trees, shrubs, linear groups of shrubs, and

Table 1 Basic characteristics of the studied parks in Skopje (North Macedonia).

Park	Area	Period of construction
Macedonia 1 Park	2.33 ha	2012-2016
Airplane Park	3.41 ha	2012
Woman-Warrior Park	1.62 ha	1970-1973

floral compositions. In contrast, Airplane Park is characterized solely by the presence of trees. All three parks are designed with a combination of informal and formal styles, with the informal style predominating. However, formal elements are also present, not only in the inanimate features such as paths and monuments but also in the plant compositions, particularly through the use of formal hedges created from shrubs. The presence of these formal elements is significant as they greatly impact the assessment of biodiversity values within the parks.

Field data collection

The data for this study were collected from the beginning of March 2023 to the end of July 2024. All woody plants (trees and shrubs) were marked using a GARMIN GPS MAP 66sr and processed with QGIS (Quantum Geographic Information System) software. Plant determination was conducted using literature on dendrology, including books by Džekov (1988), Šilić (1990), Idžojtić (2009), and databases from World Flora Online (WFO 2024), Royal Botanic Gardens, Kew (Kew 2024), and The Royal Horticulture Society (RHS 2024). Scientific names of taxa are listed according to the International Plant Names Index (IPNI 2025) and World Flora Online (WFO 2024). The authorities for scientific names are standardized according to Brummitt and Powell (1992). Cultivar names are provided according to Hoffman (2021), in accordance with the new guidelines in the "International Code of Nomenclature for Cultivated Plants" (ICNCP), which appeared in 2016 (Brickell et al. 2016). Family affiliations are listed according to Cronquist (1981), Dahlgren et al. (1985), Kramer and Green (1990), and Farjon (2010). Additionally, literature by Vidaković et al. (2020) and Idžojtić et al. (2019) was consulted. Finally, a list of all woody plants and the number of individuals belonging to each taxon for each park was compiled and used to analyze biodiversity.

Woody plant diversity analyses

Based on the collected data, a dendrological analysis of woody plants in the parks of Skopje was conducted. The analysis included the following data: the abundance of individual taxa (species, varieties, forms, hybrids, and cultivars), family affiliation, the number of woody plant taxa and plants by leaf habit, life form, and the number of native, non-native, and invasive taxa. Invasive taxa were identified according to the Global Register of Introduced and Invasive Species for North Macedonia by Trajanovski et al. (2020). Additionally, the diversity of woody plants in the studied parks was calculated using the following indices: Shannon, Simpson, Berger-Parker and Sørensen. All taxa, including hybrids and cultivars, were included in the analyses, with hybrids and cultivars of native species being classified as native, and those of non-native species classified as non-native.

The Shannon index (H') (Shannon 1948) describes both richness and evenness and is obtained based on the formula:

$$H' = -\sum_{i=1}^{s} p_i \ln (p_i)$$

where:

p_i represents the proportion of the number of taxa,

i is the total number of plants present in a given area, and

s is the total number of registered plant taxa.

The Shannon index does not have a fixed range of values but usually takes values between 1.5 and 3.5 (Magurran 2003). If the value is equal or higher than 4, the area is considered extraordinary from a biodiversity perspective.

The Simpson index (D) (Simpson 1949) is a measure for evenness. The values of this index range from 0 to 1, with higher values indicating greater uniformity within the taxa of the analyzed area. The formula used to calculate the Simpson index is as follows:

$$D = 1 - \sum_{i=1}^{s} p_i^2$$

where:

p_i represents the proportion of the number of plants of the taxa,

i is the total number of plants that are present in a given area, and

s represents the total number of plants present in a given area.

The Berger-Parker index (d) (Berger and Parker 1970) quantifies the relative abundance of the most dominant taxa. The index values range from 0 to 1, where values closer to 0 indicate higher diversity, and a value of 1 signifies a monoculture. This index is calculated using the formula:

$$d = \frac{N_{max}}{N}$$

where:

N represents the total number of plants, and

N_{max} represents the number of plants of the most abundant taxa.

The Sørensen index (Sørensen 1948) is a beta index that measures the similarity in plant composition between urban parks. The index values range from 0 to 1, with higher values, closer to 1, indicating greater similarity in the composition of plant taxa. The index is calculated using the formula:

$$SI = (2 * EC)/(E1 + E2)$$

where:

EC is the total number of plants in common between two areas,

E1 is the number of plants in Area 1 (Park 1), and

E2 is the number of plants in Area 2 (Park 2).

RESULTS

The woody plant diversity in the selected parks included 90 different taxa (60 tree taxa and 30 shrub taxa), belonging to 23 different families (Table 2). The Cupressaceae family was characterized with the highest number of taxa, with 19, while the Rosaceae family was characterized with the highest number of woody plants,

Table 2 List of woody taxa in the studied parks of Skopje (North Macedonia). Native woody plant taxa are given in green, invasive woody plant taxa are given in red.

	Taxon	Family	Macedonia 1 Park	Airplane Park	Women-Warrior Park	Total
1	*Abies concolor* (Gordon) Lindl. ex Hildebr.	Pinaceae	/	/	2	2
2	*Acer saccharinum* L.	Sapindaceae	/	/	4	4
3	*Acer negundo* L.	Sapindaceae	/	/	5	5
4	*Acer palmatum* 'Elegans'	Sapindaceae	/	/	9	9
5	*Acer platanoides* L.	Sapindaceae	/	/	2	2
6	*Acer platanoides* 'Globosum'	Sapindaceae	/	/	3	3
7	*Acer pseudoplatanus* L.	Sapindaceae	/	/	4	4
8	*Aesculus hippocastanum* L.	Sapindaceae	/	/	1	1
9	*Albizia julibrissin* Durazz.	Fabaceae	8	1	/	9
10	*Berberis thunbergii* DC.	Berberidaceae	/	/	5	5
11	*Betula pendula* Roth	Betulaceae	7	/	8	15
12	*Betula pendula* 'Youngii'	Betulaceae	12	/	/	12
13	*Buxus microphylla* Siebold et Zucc.	Buxaceae	29	/	/	29
14	*Buxus sempervirens* L.	Buxaceae	167	/	/	167
15	*Catalpa bignonioides* 'Nana'	Bignoniaceae	/	2	/	2
16	*Catalpa bignonioides* Walter	Bignoniaceae	11	/	/	11
17	*Cedrus atlantica* (Endl.) Manetti ex Carrière	Pinaceae	/	/	1	1
18	*Cedrus deodara* (Roxb. ex D.Don) G.Don	Pinaceae	/	/	16	16
19	*Chaenomeles speciosa* (Sweet) Nakai	Rosaceae	/	/	1	1
20	*Chamaecyparis lawsoniana* 'Alumii'	Cupressaceae	3	/	/	3
21	*Chamaecyparis pisifera* 'Boulevard'	Cupressaceae	5	/	/	5
22	*Cotoneaster horizontalis* Decne.	Rosaceae	5	/	/	5
23	*Cupressus sempervirens* L.	Cupressaceae	/	/	3	3
24	*Elaeagnus angustifolia* L.	Elaeagnaceae	2	/	/	2
25	*Euonymus fortunei* 'Emerald 'n' Gold'	Celastraceae	1	/	/	1
26	*Fraxinus americana* L.	Oleaceae	9	1	/	10
27	*Fraxinus angustifolia* Vahl	Oleaceae	/	/	2	2
28	*Fraxinus excelsior* L.	Oleaceae	8	9	/	17
29	*Fraxinus excelsior* 'Jaspidea'	Oleaceae	4	/	/	4
30	*Fraxinus excelsior* 'Nana'	Oleaceae	91	/	3	94
31	*Fraxinus excelsior* 'Pendula'	Oleaceae	5	/	/	5
32	*Ginkgo biloba* L.	Ginkgoaceae	18	/	/	18
33	*Ginkgo biloba* 'Mariken'	Ginkgoaceae	5	/	/	5
34	*Hedera helix* L.	Araliaceae	1	/	/	1
35	*Jasminum nudiflorum* Lindl.	Oleaceae	3	/	/	3
36	*Juniperus chinensis* 'Stricta'	Cupressaceae	3	/	/	3
37	*Juniperus communis* 'Hibernica'	Cupressaceae	5	/	/	5
38	*Juniperus horizontalis* Moench	Cupressaceae	1	/	2	3
39	*Juniperus scopulorum* 'Blue Arrow'	Cupressaceae	10	/	/	10
40	*Juniperus scopulorum* 'Skyrocket'	Cupressaceae	21	/	2	23
41	*Juniperus virginiana* L.	Cupressaceae	/	/	2	2
42	*Liriodendron tulipifera* L.	Magnoliaceae	39	9	3	51

	Taxon	Family	Macedonia 1 Park	Airplane Park	Women-Warrior Park	Total
43	*Lonicera ligustrina* var. *yunnanensis* Franch.	Caprifoliaceae	2	/	7	9
44	*Magnolia grandiflora* L.	Magnoliaceae	/	/	1	1
45	*Magnolia kobus* DC.	Magnoliaceae	/	/	1	1
46	*Magnolia* × *loebneri* Loebner	Magnoliaceae	44	/	/	44
47	*Magnolia liliiflora* Desr.	Magnoliaceae	/	/	6	6
48	*Magnolia* × *soulangeana* Soul.-Bod.	Magnoliaceae	1	/	/	1
49	*Metasequoia glyptostroboides* Hu et W.C.Cheng	Cupressaceae	3	/	/	3
50	*Parthenocissus quinquefolia* (L.) Planch.	Vitaceae	18	/	/	18
51	*Picea abies* (L.) H.Karst.	Pinaceae	/	/	13	13
52	*Picea glauca* 'Conica'	Pinaceae	2	/	/	2
53	*Picea pungens* f. *glauca* (Regel) Beissn.	Pinaceae	/	/	14	14
54	*Pinus mugo* Turra	Pinaceae	2	/	/	2
55	*Pinus nigra* J.F.Arnold	Pinaceae	1	/	95	96
56	*Pinus sylvestris* L.	Pinaceae	/	/	5	5
57	*Platanus occidentalis* L.	Platanaceae	/	/	5	5
58	*Platanus orientalis* L.	Platanaceae	/	107	13	120
59	*Platanus* × *hispanica* Mill. ex Münchh.	Platanaceae	56	32	/	88
60	*Platycladus orientalis* 'Aurea Nana'	Cupressaceae	5	/	/	5
61	*Prunus avium* (L.) L.	Rosaceae	/	3	/	3
62	*Prunus cerasifera* 'Nigra'	Rosaceae	31	/	/	31
63	*Prunus serrulata* 'Kanzan'	Rosaceae	/	131	/	131
64	*Prunus laurocerasus* 'Rotundifolia'	Rosaceae	/	/	33	33
65	*Pseudotsuga menziesii* (Mirb.) Franco	Pinaceae	/	/	1	1
66	*Pyracantha coccinea* M.Roem.	Rosaceae	/	/	4	4
67	*Quercus robur* (Fastigiata Group) 'Koster'	Fagaceae	3	/	/	3
68	*Quercus robur* L.	Fagaceae	/	/	2	2
69	*Quercus rubra* L.	Fagaceae	1	/	1	2
70	*Rosa helenae* Rehder et E.H.Wilson	Rosaceae	/	/	53	53
71	*Rosa* Floribunda Group	Rosaceae	225	/	/	225
72	*Salix* × *sepulcralis* 'Chrysocoma'	Salicaceae	6	/	/	6
73	*Salix babylonica* 'Tortuosa'	Salicaceae	/	/	1	1
74	*Scandosorbus intermedia* (Ehrh.) Sennikov	Rosaceae	6	/	2	8
75	*Spiraea japonica* 'Little Princess'	Rosaceae	32	/	/	32
76	*Taxus baccata* L.	Taxaceae	/	/	3	3
77	*Taxus baccata* 'Fastigiata'	Taxaceae	7	/	/	7
78	*Thuja occidentalis* 'Brabant'	Cupressaceae	1	/	/	1
79	*Thuja occidentalis* 'Columna'	Cupressaceae	/	/	3	3
80	*Thuja occidentalis* 'Europa Gold'	Cupressaceae	/	/	1	1
81	*Thuja occidentalis* 'Globosa'	Cupressaceae	254	/	42	296
82	*Thuja occidentalis* 'Rheingold'	Cupressaceae	1	/	/	1
83	*Thuja occidentalis* 'Smaragd'	Cupressaceae	4	/	/	4
84	*Thuja occidentalis* 'Woodwardii'	Cupressaceae	/	/	27	27
85	*Thuja plicata* Donn ex. D.Don	Cupressaceae	/	/	2	2
86	*Tilia cordata* Mill.	Malvaceae	3	/	/	3
87	*Tilia tomentosa* Moench	Malvaceae	3	/	6	9
88	*Ulmus glabra* 'Exoniensis'	Ulmaceae	4	/	/	4
89	*Ulmus glabra* 'Pendula'	Ulmaceae	6	/	/	6
90	*Wisteria sinensis* (Sims) DC.	Fabaceae	26	/	/	26

Table 3 The number of woody plant taxa and plants by leaf habit, life form, and origin in researched parks of Skopje (North Macedonia).

Category	Number of taxa				Number of plants			
	Macedonia 1 Park	Airplane Park	Woman Warrior Park	Total	Macedonia 1 Park	Airplane Park	Woman Warrior Park	Total
Evergreen/deciduous	20/33	0/9	21/24	37/53	523/697	0/295	269/150	792/1142
Evergreen/deciduous trees	3/26	0/9	16/20	17/43	32/386	0/295	161/84	193/765
Evergreen/deciduous shrubs	17/7	0/0	5/4	20/10	491/311	0/0	108/66	599/377
Conifers/broadleaves	17/36	0/9	18/27	31/59	328/892	0/295	232/187	560/1374
Conifer/broadleaves trees	4/25	0/9	15/21	17/43	35/383	0/295	161/84	196/762
Conifer/broadleaves shrubs	13/11	0/0	3/6	14/16	293/509	0/0	71/103	364/612
Trees	29	9	36	60	418	295	245	958
Shrubs	24	0	9	30	802	0	174	976
Native taxa	9	3	11	18	194	119	141	454
Non-native taxa	44	6	34	72	1026	176	278	1480
Invasive taxa	0	0	1	1	0	0	5	5
Total	53	9	45	90	1220	295	419	1934

totaling 526, which included 11 different taxa found in the researched parks. There were 42 different genera, and 21 of them have representatives of only one taxon, with five of them represented only by a single woody plant (*Aesculus* L., *Chaenomeles* Lindl., *Euonymus* L., *Hedera* L. and *Pseudotsuga* Carrière). The *Thuja* L. genus had the highest number of taxa, with eight taxa, and it also had the largest number of woody plants, totaling 335. Other genera with a higher number of taxa included *Acer* L., *Fraxinus* Tourn. ex L. and *Juniperus* L., each represented by six taxa, and *Magnolia* Plum. ex L., which was represented by five taxa. Of the total 90 different taxa, 33 were cultivars, four were hybrids, one was a variety, one was a form, and one was a cultivar of a hybrid. The remaining 51 taxa were species.

The number of woody plant taxa and plants by leaf habit, life form, and origin in researched parks of Skopje (North Macedonia) is presented in Table 3. Of the total number of woody plant taxa in all three parks, the ratio of evergreen to deciduous taxa was 41:59% (28:72% for trees and 67:33% for shrubs), and the ratio of conifers to broadleaves was 34:66% (28:72% for trees and 47:53% for shrubs) (Table 3). The ratio of evergreen to deciduous woody plants was 41:59% (20:80% for trees and 61:39% for shrubs), and the ratio of conifers to broadleaves was 29:71% (20:80% for trees and 37:63% for shrubs).

All native taxa in the studied parks are marked in green in Table 2. Only 18 of the 90 different taxa (15 tree taxa and three shrub taxa) were categorized as native (Table 3). This indicates that non-native taxa were predominantly present in the researched parks. The ratio between native and non-native woody taxa was 20:80%. In Macedonia 1 Park, there were only nine native plant taxa (17%) out of a total of 53, including six native tree taxa (21%) out of 29, and three native shrub taxa (12.5%) out of 24. Airplane Park had only three native taxa out of a total of nine (all native trees), and Woman-Warrior Park had 11 native taxa (24%) out of 45, all of which were native trees (Table 3). The largest number of native woody plants was in Macedonia 1 Park, with 194 or 16% of all native woody plants (1220) (Table 3). However, considering that all native shrubs were in this park (170 shrubs or 21% of all shrubs in the park), Macedonia 1 Park had the smallest number of native trees (only 24 trees or 6% of all 418 trees in the park) compared to other researched parks (Airplane Park with 119 plants or 40% of a total 295, and Woman-Warrior Park with 141 individuals or 37% native individuals of a total of 419) (Table 3).

Of the 72 non-native woody plant taxa present in the researched parks, only one, *Acer negundo* L., was invasive. This species was found only in one of the researched parks (Woman-Warrior Park), with just five trees (Table 2, Table 3).

Table 4 The Shannon, Simpson, and Berger-Parker indices of woody plant diversity in the studied parks.

Park	Shannon index	Simpson index	Berger-Parker index
Macedonia 1 Park	2.66	0.89	0.53
Airplane Park	1.30	0.66	0.92
Woman-Warrior Park	2.76	0.89	0.53

Table 5 Sørensen index of woody species biodiversity between the studied parks.

Sørensen index	Macedonia 1 Park	Airplane Park	Woman-Warrior Park
Macedonia 1 Park	1		
Airplane Park	0.23	1	
Woman-Warrior Park	0.36	0.12	1

The values of the alpha biodiversity indices in the studied parks are shown in Table 4. The Shannon index had the highest value of 2.76 in Woman-Warrior Park, slightly lower in Macedonia 1 Park at 2.66, and significantly lower in Airplane Park at 1.30. The Simpson index had especially high values in two of the parks, Macedonia 1 Park and Woman-Warrior Park, both with a value of 0.89, indicating a quite highly homogeneous distribution of plant taxa in these parks. In Airplane Park, the value was slightly lower, at 0.66. Furthermore, the Berger-Parker index was the highest in Airplane Park (0.92), indicating very low diversity. The values of the Berger-Parker index in the other two parks were lower, 0.53 for both Macedonia 1 Park and Woman-Warrior Park, but they still represent a quite high abundance of the most dominant taxa.

Using the Sørensen beta index, the similarity between the researched parks was determined. The values of the Sørensen index of woody species biodiversity between the selected parks are presented in Table 5. In accordance with this research, the greatest similarity, with a Sørensen index value of 0.36, was observed between Macedonia 1 Park and Woman-Warrior Park. However, this value still indicates very small similarity. The remaining Sørensen index values were notably low: 0.12 between Airplane Park and Woman-Warrior Park, and 0.23 between Macedonia 1 Park and Airplane Park, indicating significant differences in their plant compositions.

DISCUSSION

The presence of deciduous broadleaved taxa dominates the entire researched area, as well as each of the individual parks. From the analysis of trees, it is evident that deciduous broadleaved tree taxa are dominant. Moreover, in one of the parks (Airplane Park), the absence of evergreen plants is noticeable, with all woody plants being deciduous broadleaved. Although the shade provided by deciduous trees is considered the optimal shading solution and effectively meets the demands for thermally comfortable spaces (Xu et al. 2019), this choice of vegetation creates empty landscapes in late autumn and winter, negatively impacting biodiversity and the maintenance of ecosystem services (Nagendra and Gopal 2011). In addition, the analysis of shrubs shows that evergreen and broadleaved shrubs are dominant in the studied parks.

The presence of native woody taxa and the abundance of native plants across all the surveyed parks in Skopje are notably low. According to some authors (Lanta et al. 2013, Lakičević et al. 2022, Öğçe et al. 2022), urban spaces should prioritize the selection of native species over non-native ones. In general, native species are better adapted to local climate conditions and can significantly improve the quality of urban ecosystems. In addition, these species are crucial for maintaining local biodiversity, supporting wildlife, and providing ecosystem services. Besides being better adapted to the local environment and climatic conditions, they require less maintenance and, in terms of decorativeness, they are not inferior to non-native species (Tafra et al. 2012). Nevertheless, non-native species are often chosen over native ones for urban landscaping due to their aesthetic appeal, fast growth, beautiful flowers, interesting foliage, and exotic appearance (Idžojtić et al. 2010, 2011, 2013; Poljak et al. 2011; Špaková and Šerá 2018). People often enjoy introducing exotic plants to create visually appealing and diverse landscapes (Zebec et al. 2014). However, the replacement of native species with non-native ones can undermine essential ecological functions provided by vegetation, and some of these functions may be completely lost (Talal and Santelmann 2019). Ultimately, this can negatively affect biodiversity in the urban environment. Although a significant number of studies have found that in urban parks, non-native taxa are more prevalent than native ones (Rauš 1969; Karavla 1997; Godefroid 2001; Wania et al. 2006; Shochat et al. 2010; Poljak et al. 2011; Tafra et al. 2012, 2013; Zebec et al. 2014; Gaertner et al. 2017; Pušić et al. 2023), there are also examples where native species have increased and non-native taxa have decreased in certain parks. For example, in King Petar Krešimir IV Park in Zagreb, Croatia, this shift occurred between 1995 and 2020 as a result of efforts focused on preserving biodiversity (Vidaković et al. 2020). On the contrary, some studies indicate that in the context of a changing climate, greater attention should be given to the potentially positive role of non-native, climate-adapted, aesthetically pleasing species in urban planting schemes, as these could be well-received by the public (Hoyle et al. 2017).

Among the non-native taxa in the researched parks of Skopje, only one is invasive, and it was recorded in only one park, Woman-Warrior Park. It is well known that invasive plant species represent one of the major threats to global biodiversity, including urban biodiversity (Francis and Chadwick 2015, Williams et al. 2015, Kaushik et al. 2022). These species often act as pioneer species in different landscapes, are tolerant to disturbances, climatic conditions, and climate change, and have high competitive potential, which results in the loss of native flora (Kaushik et al. 2022). However, in the researched urban parks in Skopje, we can conclude that the situation is under control, and there is currently no threat posed by invasive species to urban plant biodiversity. The presence of only one invasive species in only one of the researched parks, with just five trees in total, is completely insignificant. In general, in urban parks like the researched ones, which are consistently managed through planning and maintenance, with no larger areas in a typical landscape style, the probability of invasive species occupying the space is very low. Nevertheless, in the future, special attention is recommended when introducing new woody taxa to ensure they do not possess invasive characteristics (Burton et al. 2005, Fuller et al. 2007, Kowarik 2011, Trentanovi et al. 2013, Wood et al. 2018).

Most of the native trees in the parks are older, indicating a decline in the use of native woody plants in urban green areas compared to the past, and an increasing use of non-native and exotic species in recent times. The oldest and largest trees were found in Woman-Warrior Park, where the largest number of native trees were planted during the construction of the park in the early 1970s. These species include *Pinus nigra* J.F.Arnold, *Platanus orientalis* L., *Betula pendula* Roth, *Tilia tomentosa* Moench, *Pinus sylvestris* L. and *Quercus robur* L. Specifically, the most striking specimens are those of the genus *Platanus* L., with an average diameter at breast height (DBH) of 61 cm. Notably dominant is one specimen of *Platanus orientalis*, with a remarkable DBH of 112 cm, along with three other trees measuring 96 cm. These four trees are believed to have been part of the area even before the park's construction. Generally, such old and large trees are keystone structures in urban parks and they are recognized for their biodiversity values (Jonsell 2004, Stagoll et al. 2012, Zebec et al. 2014) and for their ecological, historical and sociocultural importance (Tyrväinen et al. 2005, Poljak et al. 2011, Nolan et al. 2020). The other two parks are relatively new (since 2012), and they lack such old and large trees. Most of the trees in the other two studied parks have an average diameter of less than 30 cm.

The diversity of woody taxa in the researched parks was also analyzed using the biodiversity indices. The Shannon index values obtained for the researched parks indicate that none of the parks fall into the category of extraordinary biodiversity, which is defined by a value equal to or higher than 4 (Magurran 2003). In fact, Airplane Park has a particularly low Shannon index value of 1.30, which is even below the usual range of 1.5-3.5 (Shannon 1948). This was also confirmed by the Berger-Parker index, where values closer to 0 correspond to higher diversity, and a value of 1 indicates a monoculture (Berger and Parker 1970). Airplane Park had a value slightly above 0.9, indicating that it is very close to being a monoculture. The park is characterized by a high abundance of the following taxa: *Platanus* × *hispanica* Mill. ex Münchh., *Platanus orientalis* and *Prunus serrulata* 'Kanzan'. In addition, the values of the Simpson index indicated a highly homogeneous distribution of woody plant taxa, especially in two parks: Macedonia 1 Park and Woman-Warrior Park. Finally, the similarity between the researched parks was determined using the Sørensen beta index. According to the rule that values closer to 1 correspond to greater similarity in plant composition (Sørensen 1948), it can be concluded that there is a lack of significant similarity among the parks. From a biodiversity perspective, parks with a diverse plant composition are more beneficial than those with uniform plant components, which is why the analysis of beta indices for different habitats/parks is of great importance (Lakičević et al. 2022). Therefore, although the alpha indices suggest a lower to moderate diversity of woody taxa in the researched parks, the beta index suggest significant differences between the parks in terms of the presence of woody taxa.

CONCLUSIONS

Biodiversity studies are of great importance for raising awareness about nature preservation in the urban environment and improving urban life. In this study of three parks in the city of Skopje, a total of 90 different woody plant taxa were identified, which is somewhat lower compared to some other cities in Europe. Generally speaking, the surveyed parks have a significantly higher number of deciduous taxa compared to evergreen taxa, and a significantly higher number of non-native taxa compared to native taxa. Overall, the interrelated values of the calculated alpha indices contribute to a low level of species richness across the studied parks. While the values of the alpha indices indicate a negative impact on biodiversity, the Sørensen beta index reveals a positive perspective, highlighting a lack of significant similarity among the researched parks.

Since none of the parks is characterized by great biodiversity, the recommendations emphasize the need to enhance the biodiversity of woody plants in Skopje and to monitor it continuously. Biodiversity considerations should be integrated into the process of planning and landscape designing of urban parks, as well as in their maintenance, including the regular replacement of plants. Finally, this research can inform future studies by comparing biodiversity across parks and different time periods in the territory of Skopje, providing guidance for urban planners and landscape designers. Regular monitoring of woody plant diversity in urban parks should be established as a standard practice, as it is essential for understanding the actual situation and enabling timely interventions.

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LEAF MORPHOLOGICAL VARIATION IN *Ribes alpinum* L. ACROSS ELEVATION GRADIENTS IN THE NORTH-WESTERN DINARIC ALPS: EVIDENCE OF PHENOTYPIC PLASTICITY AND HABITAT INFLUENCE

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SUMMARY

Mountain ecosystems are shaped by steep environmental gradients that influence plant morphology and adaptation. *Ribes alpinum* L., a deciduous shrub with a wide European distribution, remains poorly studied in terms of its intraspecific variability. This study aimed to investigate leaf morphological variation across five natural populations from the Dinaric Alps, focusing on differences in leaf size and shape in relation to elevation and habitat conditions. Leaves were sampled from four populations and photographed *in situ* at a fifth site located within a strict nature reserve. Ten morphometric traits were measured – five related to leaf size (e.g., area, length, petiole length) and five describing leaf shape and lobe configuration. Statistical analyses revealed significant differences among populations in seven traits, with leaf size parameters showing the greatest divergence. Populations from contrasting elevations were consistently identified as morphologically distinct. The low-elevation population showed the greatest degree of within-population morphological diversity, likely reflecting the influence of heterogeneous terrain and fine-scale microhabitat variation. Multivariate analyses (PCA and clustering) confirmed population-level structuring, while Redundancy Analysis (RDA) showed that geographic coordinates had no significant influence on trait variation. Instead, elevation-related environmental gradients emerged as the dominant drivers of morphological differentiation. These findings suggest that leaf traits in *Ribes alpinum* are shaped primarily by local ecological pressures, reflecting phenotypic plasticity rather than broad spatial separation. The study highlights the adaptive flexibility of *Ribes alpinum* and underscores the ecological importance of the Dinaric Alps as a valuable setting for investigating plant responses to environmental heterogeneity.

KEY WORDS: Dinaric Alps, alpine shrub, leaf morphometry, elevation gradient, phenotypic plasticity, habitat heterogeneity, intraspecific variation, mountain flora adaptation

INTRODUCTION

Mountain ecosystems are among the most ecologically and biogeographically distinctive regions on Earth. Characterized by steep environmental gradients, fragmented landscapes, and pronounced spatiotemporal heterogeneity, they often function as isolated ecological islands (Körner 2003, Flantua et al. 2020). These environments support a high number of endemic and specialized species, particularly among plants adapted to narrow altitudinal niches (Lomolino 2001, Steinbauer et al. 2016, Perrigo et al. 2019). Yet, the same factors that foster diversification also make mountain flora especially vulnerable to environmental disturbances. Climate change and land-use pressures increasingly threaten alpine and subalpine plant populations (Steinbauer et al. 2018, Hanjalić Kurtović et al. 2025), many of which are confined to

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rear-edge habitats with limited dispersal potential (Watts et al. 2022). Understanding the variability of mountain plants is therefore essential – not only for documenting their adaptive strategies, but also for guiding conservation efforts aimed at preserving evolutionary potential under accelerating global change.

The morphology of mountain plants is shaped by a complex interplay of abiotic stressors and microhabitat diversity. Alpine environments impose extreme conditions – low temperatures, high UV radiation, short growing seasons, and mechanical stress from wind and snow – that favour compact growth forms, reduced stature, and specialized leaf and root traits (Körner 2003). Morphological adaptations such as reduced plant height, dense leaf hairiness, cushion-like or rosette architecture, and robust root systems are common strategies that enhance thermal buffering, reduce water loss, and protect meristems from frost damage (Neuner 2014, Zhang et al. 2021, Rai et al. 2025). These traits are not merely passive responses but reflect evolutionary innovations that enable survival in topographically complex and climatically unstable habitats.

One of the most influential factors shaping leaf morphology in alpine plants is altitudinal variation. Elevation affects temperature regimes, atmospheric pressure, and solar radiation intensity, all of which directly influence leaf size, thickness, and anatomical structure (Körner et al. 1989, Körner 2003). Numerous studies have shown that leaf area tends to decrease with increasing elevation (Körner et al. 1986, Milla and Reich 2011, Poljak et al. 2018, Liu et al. 2020, Ke et al. 2022), while traits such as leaf hairiness and margin complexity often increase as adaptive responses to harsher conditions (Körner 2003, Moles et al. 2020, Wang et al. 2022). Additionally, topographic heterogeneity creates fine-scale habitat mosaics (Bruun et al. 2006, Ford et al. 2013, Bueno de Mesquita et al. 2018), where soil moisture, snow cover duration, and nutrient availability vary dramatically over short distances. These environmental pressures frequently lead to high intraspecific morphological variability (Körner 2003, Boucher et al. 2013, Opedal et al. 2015), especially in traits related to leaf size, shape, and architecture. Such variability may reflect both phenotypic plasticity and underlying genetic differentiation (Gonzalo-Turpin and Hazard 2009), making morphometric analyses a valuable tool for detecting population-level divergence and potential local adaptation.

Ribes alpinum L. – commonly known as mountain or alpine currant – is a deciduous shrub from the family Grossulariaceae, typically reaching up to 1.5 meters in height (Schütt 2011). It lacks spines and features small, palmately lobed leaves (up to 5 cm), with finely toothed margins and a variable number of lobes (usually three to five). The species is functionally dioecious, with male inflorescences forming upright racemes of 10–30 flowers, and female racemes bearing 2–10 flowers (Idžojtić 2019). The fruits are smooth, red berries with little taste, maturing in mid to late summer. Despite its wide distribution across Europe and southwestern Asia (Hegi 1961, Krüssmann 1962), *Ribes alpinum* remains poorly studied from a morphological and ecological perspective. Most available data are limited to floristic records and general habitat descriptions (Horvat 1937, Vukelić and Rauš 1998, Vukelić et al. 2011, Vukelić 2012, Dakskobler and Rozman 2021, Sirovica 2025), with no insights into its adaptive traits or population-level differentiation.

Ecologically, *Ribes alpinum* occupies a broad range of habitats – from lowland forests in northern Europe to montane and subalpine zones in the south (Weber 1995). In Central and Northern Europe, it grows from sea level up to approximately 2000 meters, with upper elevation limits reaching around 2020 meters in the Swiss Alps (Schütt 2011). However, in southern parts of its range – including the Dinaric Alps – the species is largely restricted to mountainous terrain. In the Dinarides, *Ribes alpinum* is typically found along forest edges and rocky slopes, but it also colonizes open high-altitude habitats such as dwarf pine (*Pinus mugo* Turra) shrublands (Horvat 1937, Vukelić 2012). It thrives in shady microhabitats with moderate soil moisture (Ellenberg 1979), often within mixed stands of beech (*Fagus sylvatica* L.), fir (*Abies alba* Mill.), spruce (*Picea abies* (L.) H.Karst.), and sycamore maple (*Acer pseudoplatanus* L.) (Vukelić et al. 2011). The Dinaric Alps are especially notable for their rich plant diversity and ecological complexity (Médail and Diadema 2009, Brus 2010, Médail et al. 2019, Liber et al. 2020), yet no prior research has examined how these conditions influence morphological variation in *Ribes alpinum*, making the region an ideal setting for studying adaptive responses in mountain flora.

This study investigates leaf morphology across five natural populations of *Ribes alpinum* in Croatia, sampled from sites differing in elevation, habitat structure, and microclimatic conditions. The populations span both shaded forest margins and open subalpine habitats, including dwarf pine shrublands. Through detailed morphometric analyses, we aim to quantify variation within and among populations and assess the extent to which this variation is shaped by geographic factors, as well as environmental conditions like elevation, light exposure, temperature, and precipitation. Importantly, we consider the role of phenotypic plasticity, recognizing that the observed morphological differences may reflect flexible responses to local conditions rather than fixed genetic divergence. We hypothesize that (1) leaf morphology will vary significantly with elevation and habitat openness, and (2) populations from higher altitudes and more exposed sites will exhibit traits associated with alpine adaptation, such as reduced leaf size. By disentangling the relative influence of geographic and environmental drivers, this research contributes to a deeper understanding of plant adaptation in mountain ecosystems and highlights the ecological significance of the Dinaric Alps as a natural laboratory for studying evolutionary processes.

MATERIALS AND METHODS

Sample collection

During the 2023 field season, fully developed and intact alpine currant leaves were sampled from five natural populations across the Dinaric Alps in Croatia: Snježnik (P1), Risnjak (P2), Bijele and Samarske stijene (P3), Zavižan (P4), and Zečjak (P5) (Table 1, Figure 1). From four populations (P1, P2, P4, and P5), leaf material was physically collected in the field and immediately stored in cardboard folders for transport to the Herbarium DEND (Faculty of Forestry and Wood Technology, University of Zagreb), where it was permanently deposited. At each site, 20 leaves were collected from as many individual shrubs as possible, usually between 7 and 12 shrubs per site. In the case of the P3 population, located within the strictly protected Bijele and Samarske stijene nature reserve, sampling was carried out through *in situ* photographic documentation with a visible scale, and subsequent morphometric analyses were performed using these images. All fieldwork in the protected areas was conducted under official permission granted by the Ministry of Economy and Sustainable Development (UP/I 612-07/21-33/57, UP/I-352-04/24-08/18).

Table 1 Populations, sampling sites, geographic coordinates, altitude, and bioclimatic variables (BIO1, BIO9, BIO17) used in redundancy analysis (RDA), along with multivariate diversity index (MDI) for five mountain currant (*Ribes alpinum* L.) populations. Bioclimatic variables: BIO1 (mean annual temperature), BIO9 (mean temperature of the driest quarter), and BIO17 (precipitation of the driest quarter).

Population ID	Population	Latitude	Longitude	Altitude	BIO1	BIO9	BIO17	MDI
P1	Snježnik	45.443076	14.577918	1391	4.48	-2.53	382	3.12
P2	Risnjak	45.427662	14.622818	1384	4.39	-2.60	384	2.18
P3	Bijele and Samarske stijene	45.225201	14.968227	1280	5.48	-1.58	356	4.60
P4	Zavižan	44.801167	14.972380	1608	4.00	11.85	358	3.43
P5	Zečjak	44.702748	14.992914	1600	4.08	11.97	345	2.84

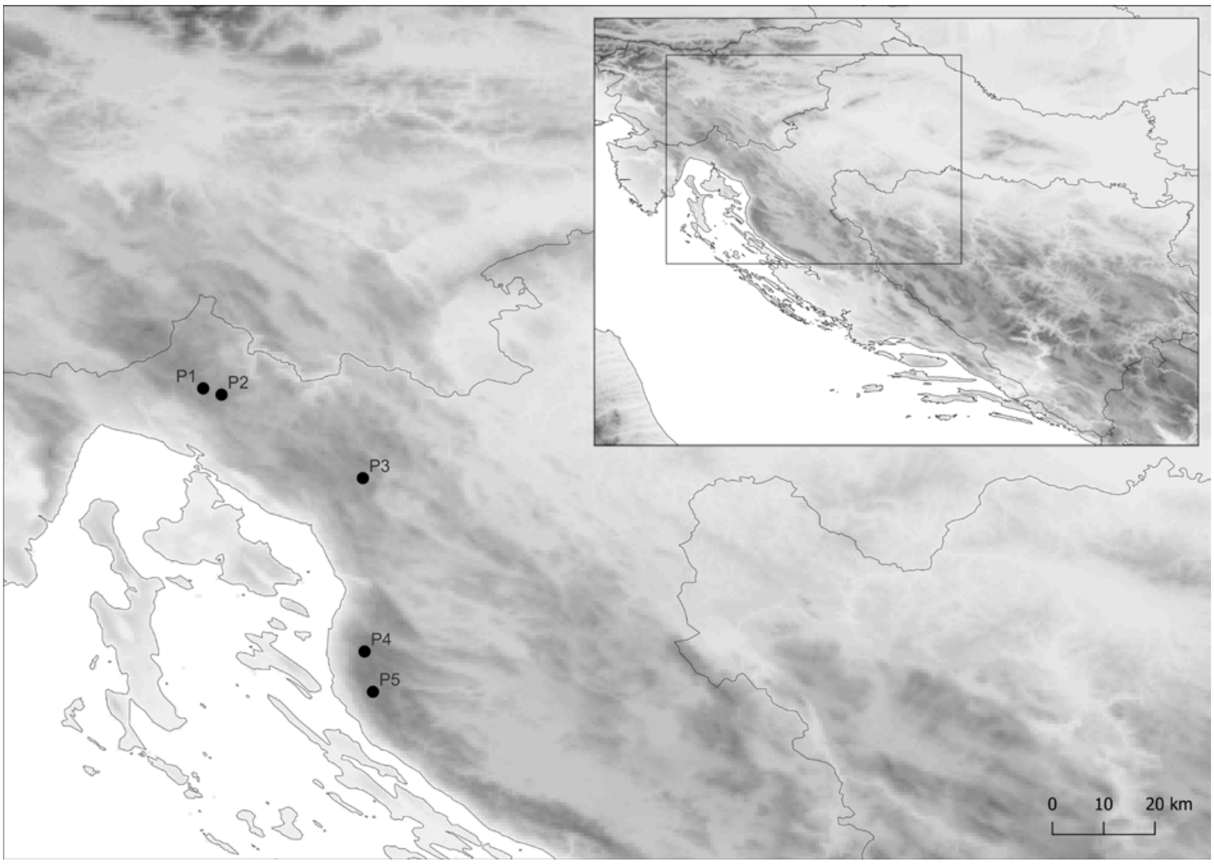

Figure 1 Geographic distribution of the five natural populations of mountain currant (*Ribes alpinum* L.) sampled in the Dinaric Alps. Populations are labelled as follows: P1 – Snježnik, P2 – Risnjak, P3 – Bijele and Samarske stijene, P4 – Zavižan, and P5 – Zečjak.

Morphometric analysis

Following field collection, all mountain currant leaves were immediately pressed between absorbent sheets to ensure flattening and desiccation, and subsequently herbarized. Dried leaves were scanned at 600 dpi using a MICROTEK ScanMaker 4800 and saved in TIFF format. Leaf outlines were analysed using WinFolia™ 2001 software, together with *in situ* photographs from the Bijele and Samarske stijene population (P3). A total of ten morphological parameters were measured (Table 2, Figure 2), including traits related to leaf size and shape. Measurements were performed using the "Leaf Morphology" and "Interactive Measurements" functions, focusing on overall dimensions, petiole length, base angles, and lobe geometry. Acronyms and detailed trait definitions are provided in Table 2.

Statistical analysis

Descriptive statistical analyses were carried out for all examined traits in accordance with the methodology outlined by Sokal and Rohlf (2012). The following parameters were calculated: arithmetic mean, median, minimum, maximum, lower quartile (Q1), upper quartile (Q3), standard deviation, and coefficient of variation (%). These statistics were computed collectively across all samples (45 shrubs) using the dplyr package (Wickham et al. 2025) in R Statistical Software (v4.4.0, R Core Team 2025).

Table 2 Leaf morphometric traits included in this research.

Trait acronym	Trait
LA	Leaf area (cm^2)
LL	Leaf length (cm)
MLW	Maximal leaf width (cm)
PMLW	Distance from the leaf base to the point of maximal leaf width (cm)
PL	Petiole length (cm)
LBA1	Angle closed by the main leaf vein and the line defined by the leaf blade base and a point on the leaf margin at 10% of leaf blade length (°)
LBA2	Angle closed by the main leaf vein and the line defined by the leaf blade base and a point on the leaf margin at 25% of leaf blade length (°)
ALA	Angle between the vectors drawn from the leaf base to the tips of the left and right lobes (°)
SAC	Angle enclosed between the sinuses of the left and right lobes and the apex of the central lobe (°)
LTA	Angle formed by the apex of the left lateral lobe, the apex of the central lobe, and the point at the sinus separating them (°)

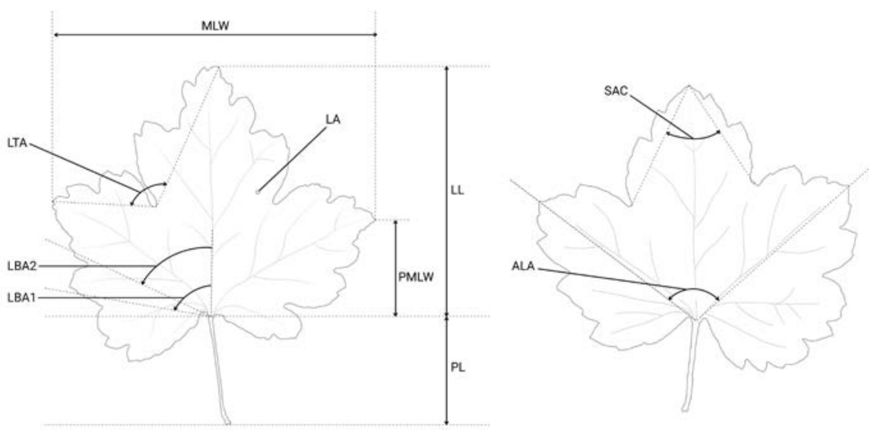

Figure 2 Measured leaf morphological traits of *Ribes alpinum* L. (for description see Table 2). Illustration created by Anamarija Zegnal.

To assess differences among populations, a one-way analysis of variance (ANOVA) was performed for each trait using the aov() function, followed by Tukey's Honest Significant Difference (HSD) test via the TukeyHSD() function. Homogeneous groups were identified with the aid of the multcompView package (Graves et al. 2024), and labelled using letter annotations (e.g., "a", "ab", "b", "bc", "c") to indicate statistically non-significant differences.

Box plots were generated for each trait using ggplot2 package in R (Wickham 2016) to visualize trait distributions across populations. Each box plot displays the first quartile (Q1), third quartile (Q3), and the interquartile range (IQR = Q3 − Q1). The whiskers extend to the smallest and largest values within 1.5 × IQR from the lower and upper quartiles, respectively. Outliers beyond this range are shown as individual points. The median, representing the central tendency of the data, is depicted as a horizontal line within the box. Letter groupings derived from Tukey's HSD tests were displayed above each box to indicate statistically homogeneous groups.

Principal component analysis (PCA) was conducted to examine patterns of variation among individuals and populations based on morphometric traits. The analysis was performed in R using the FactoMineR (Lê et al. 2018), factoextra (Kassambara and Mundt 2020), and ggplot2 (Wickham 2016) packages. Prior to PCA, input variables were standardized, and trait columns were filtered to retain only numerical data. Eigenvalues, explained variance, and loadings were extracted to assess component significance and trait contributions. Visualization outputs included scree plots and variable contribution diagrams, providing insights into trait influence on principal components. A biplot was constructed using the first two principal components, allowing simultaneous interpretation of both individual clustering and variable orientations. Contributions ($\cos^2$ values and percentage influence) of individual traits and samples were calculated and graphically represented to identify patterns of association and structural differentiation among populations.

Euclidean distances were calculated between all pairs of individuals based on their scores from the first two principal components, considering a total of 10 leaf morphological parameters. The mean Euclidean distance within each population was used to derive a multivariate diversity index (MDI) as described by Poljak et al. (2024).

The clustering tendency of the dataset was assessed using the Hopkins statistic, implemented via the hopkins() function from the clustertend package in R (Wright et al. 2023). This test was used to determine the appropriateness of applying cluster-based algorithms. To identify the optimal number of clusters, several validity indices – including silhouette width and within-cluster sum of squares – were examined across multiple k-values. Based on these evaluations, k-values of 3 and 4 were selected for further analysis. K-means clustering was performed using standardized leaf trait variables through the kmeans() function in R. The resulting cluster memberships were visualized using scatter plots generated with the factoextra (Kassambara and Mundt 2020) and ggplot2 (Wickham 2016) packages, providing a graphical overview of the sample distribution across clusters.

To explore the influence of geographic and environmental factors on leaf morphology in *Ribes alpinum*, 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). Leaf morphological traits showing lower intercorrelation ($r < 0.85$) and significant population-level differentiation were selected as response variables. Prior to ordination, these traits were Hellinger-transformed to reduce scale dependency and conform to assumptions of constrained ordination. Predictor variables were categorized into two sets: geographic predictors, which included latitude and longitude, and environmental predictors, comprising altitude and bioclimatic variables. Altitude data were obtained independently using GPS measurements, while bioclimatic data were retrieved from WorldClim v2.1 (Fick and Hijmans 2017) at 30 arc-second resolution. Initial environmental dataset included 19 bioclimatic layers; multicollinearity among them was addressed using the vifstep procedure from the usdm package (Naimi et al. 2014), retaining BIO1 (mean annual temperature), BIO9 (mean temperature of the driest quarter), and BIO17 (precipitation of the driest quarter) as final climatic predictors. All predictors were standardized (z-transformed) prior to the analysis. To partition variation attributable to climate and geography, three RDA models were constructed: (1) a full RDA model including both environmental and geographic predictors; (2) a partial RDA where environmental effects were conditioned on geography (environment | geography); and (3) a partial RDA where geographic effects were conditioned on environment (geography | environment). Significance of the models was assessed using permutation tests (999 iterations), and adjusted R^2 was used to evaluate explanatory power. Ordination scores for sites, traits, and predictors were visualized in biplots using ggplot2 (Wickham 2016), with enhancements via ggrepel (Slowikowski 2024) and ggsci palettes (Xiao 2024).

RESULTS

Descriptive statistics for each trait across all 45 shrubs in the overall sample are presented in Table 3. On average, leaves of *Ribes alpinum* measured 1.98 cm in length and 2.21 cm in width, with petioles averaging 1.57 cm. Among all measured traits, the least variable were the leaf base angles (LBA1 and LBA2), with coefficient of variation (CV) values of 3.27% and 3.76%, respectively. Angles obtained through interactive measurements also exhibited low variability, with CVs ranging from 7.81%

Table 3 Descriptive statistics of morphological variability in mountain currant (*Ribes alpinum* L.) across five populations in the Dinaric Alps, Croatia. Trait acronyms as in Table 2.

Trait	Descriptive parameters							
	Mean	Median	Minimum value	Maximum value	1st quartile	3rd quartile	Standard deviation	Coefficient of variation (%)
LA (cm^2)	3.16	2.94	0.96	9.69	2.05	3.42	1.76	55.8
LL (cm)	1.98	1.94	1.21	3.57	1.70	2.06	0.49	24.6
MLW (cm)	2.21	2.05	1.19	3.91	1.90	2.46	0.57	25.7
PMLW (cm)	0.85	0.80	0.47	1.60	0.72	0.93	0.24	27.8
PL (cm)	1.57	1.46	0.71	3.31	1.25	1.83	0.54	34.6
LBA1 (°)	74.8	75.2	65.8	79.0	73.8	76.1	2.44	3.27
LBA2 (°)	61.9	61.8	56.4	67.2	60.5	63.3	2.33	3.76
ALA (°)	111	111	90.1	130	107	117	8.67	7.81
SAC (°)	54.9	54.9	39.0	68.6	50.0	58.5	6.74	12.3
LTA (°)	85.4	84.9	69.2	108	79.5	90.5	7.91	9.25

to 12.3%. In contrast, LA was by far the most variable trait, with a CV of 55.8%, followed by petiole length (PL) at 34.6%. Other traits related to leaf dimensions showed medium to high variability across the sample. Leaf length (LL) had a CV of 24.6%, maximum leaf width (MLW) of 25.7%, and the position of maximum width (PMLW) of 27.8%. Although these values were lower than those for leaf area and petiole length, they still reflected a substantial degree of morphological variation.

Descriptive statistics and results of the Tukey's HSD test are presented in Figure 3. The analysis revealed clear distinctions among populations based on leaf morphology, with statistically significant differences observed in seven out of ten traits: LA, LL, MLW, PMLW, PL, ALA and SAC. Population P3 consistently formed a separate homogeneous group, showing significantly higher values for leaf area (LA), leaf length (LL), maximal leaf width (MLW), petiole length (PL), and the distance to maximal leaf width (PMLW). In contrast, populations P1, P2, and P4, frequently grouped together, showed similar trait values, while P5 displayed intermediate values and occasionally overlapped with other groups. Population P4, within this broader cluster, consistently displayed the lowest median values for LA, LL, MLW, and PMLW. For LL and MLW in particular, P4 formed a distinct homogeneous group, underscoring its tendency toward reduced leaf size compared to all other populations. When examining traits related to leaf base and apex geometry (LBA1, LBA2, and LTA), all populations fell into a single homogeneous group, indicating high uniformity in these structural parameters. Meanwhile, traits associated with lobe configuration – namely ALA and SAC – showed moderate differentiation. For ALA, P4 was grouped with P2 and P3, forming a subset with higher values, whereas P1 and P5 fell into a group with lower trait expression. Regarding SAC, P4 was classified into group "a", while P5 formed a distinct group "b"; the remaining populations (P1, P2, and P3) occupied overlapping groupings ("ab"), indicating intermediate positioning. These patterns suggest that although P4 did not always form an entirely separate group, it consistently tended toward elevated values in lobe angle traits.

The first three principal components had eigenvalues above 1, and explained 92.3% of total variability. The first principal component, which explained 52.7% of total variability, was in a high positive correlation with LA, LL, MLW, PMLW and PL, i.e. all of the morphometric parameters referring to the leaf size. The second principal component explained additional 28.4% of total variability, and was highly positively correlated with LBA1, LBA2 and LTA (Figure 4). Additional 11.2% of total variability was explained by the third principal component, which was positively correlated with SAC. The biplot of the principal component analysis based on 10 morphological parameters is shown in Figure 4. Although most of the samples were highly intermixed, a clear separation of populations Zavižan (P4) and Bijele and Samarske stijene (P3) along the first PC axis is visible. Namely, individuals within population Zavižan (P4) were grouped on the left side of the diagram, and characterized by the smallest leaves, while individuals within population Bijele and Samarske stijene (P3) were grouped on the right side of the diagram and characterized by the largest leaves.

To evaluate morphological variability within populations, a multivariate diversity index (MDI) was calculated for each of the five studied populations based on the mean Euclidean distance between individuals, derived from their scores along the first two principal components encompassing ten leaf morphological traits (Table 1). The highest intra-population diversity was observed in the Bijele and Samarske stijene population (P3, MDI = 4.60), followed by Zavižan (P4, MDI = 3.43), Snježnik (P1, MDI = 3.12), and Zečjak (P5, MDI = 2.84), while the lowest diversity was recorded in Risnjak (P2, MDI = 2.18). These values reveal notable variation in leaf morphology among individuals across populations.

Clustering tendency was confirmed by a high Hopkins statistic (0.9988), indicating a strong underlying structure suitable for clustering. Based on silhouette analysis and other validation indices, both three-cluster (k = 3) and four-cluster (k = 4) solutions were identified as optimal.

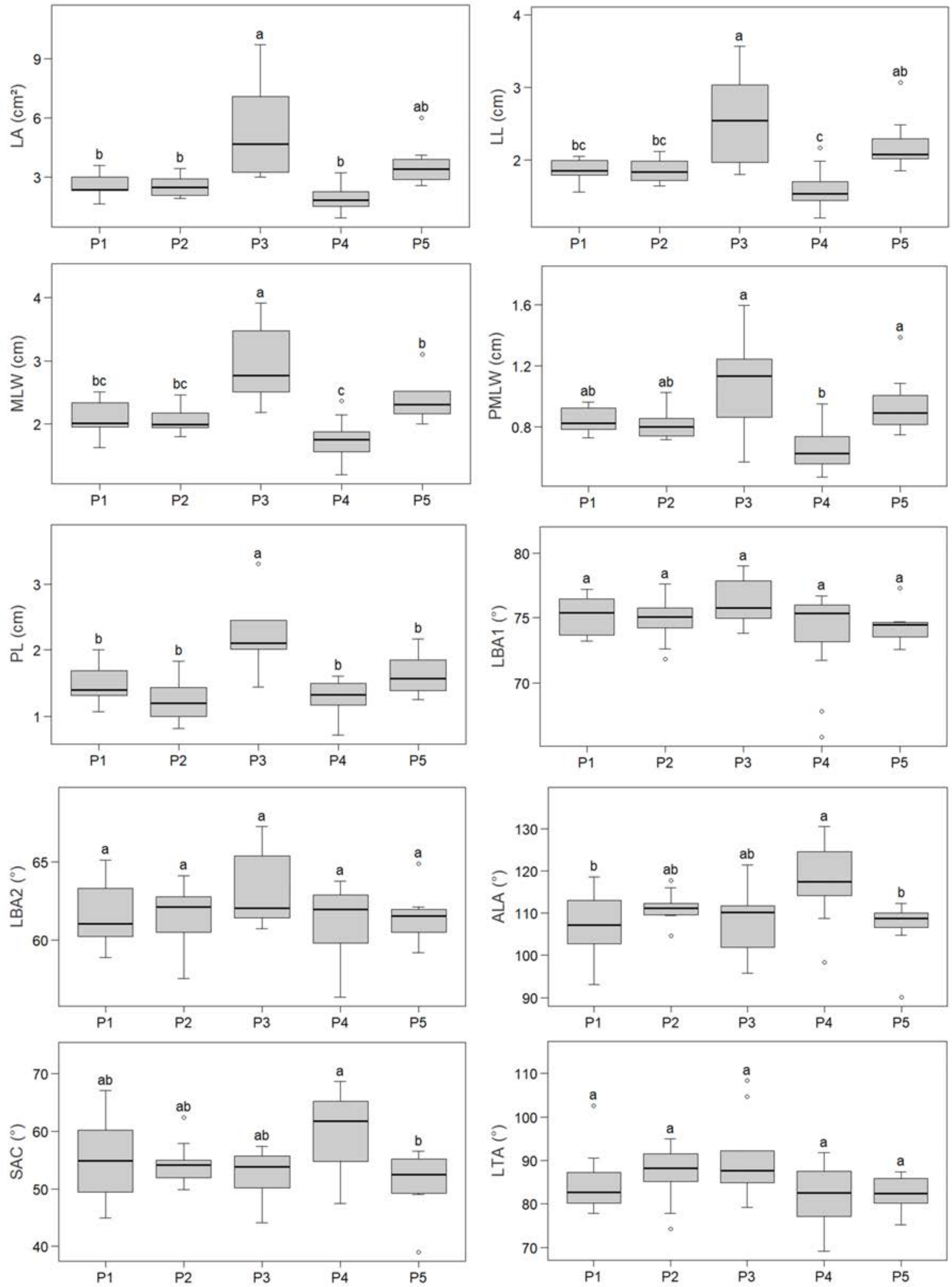

Figure 3 Variation in leaf morphological traits across five natural populations of mountain currant (*Ribes alpinum* L.) in the Dinaric Alps illustrated by box plots showing the first and third quartiles, interquartile range, and median values, with whiskers extending 1.5 times the interquartile range, outliers depicted as individual points, and statistically homogeneous groups identified by letter annotations based on Tukey's HSD tests following one-way ANOVA. Populations labelled as in Table 1 and trait acronyms as in Table 2.

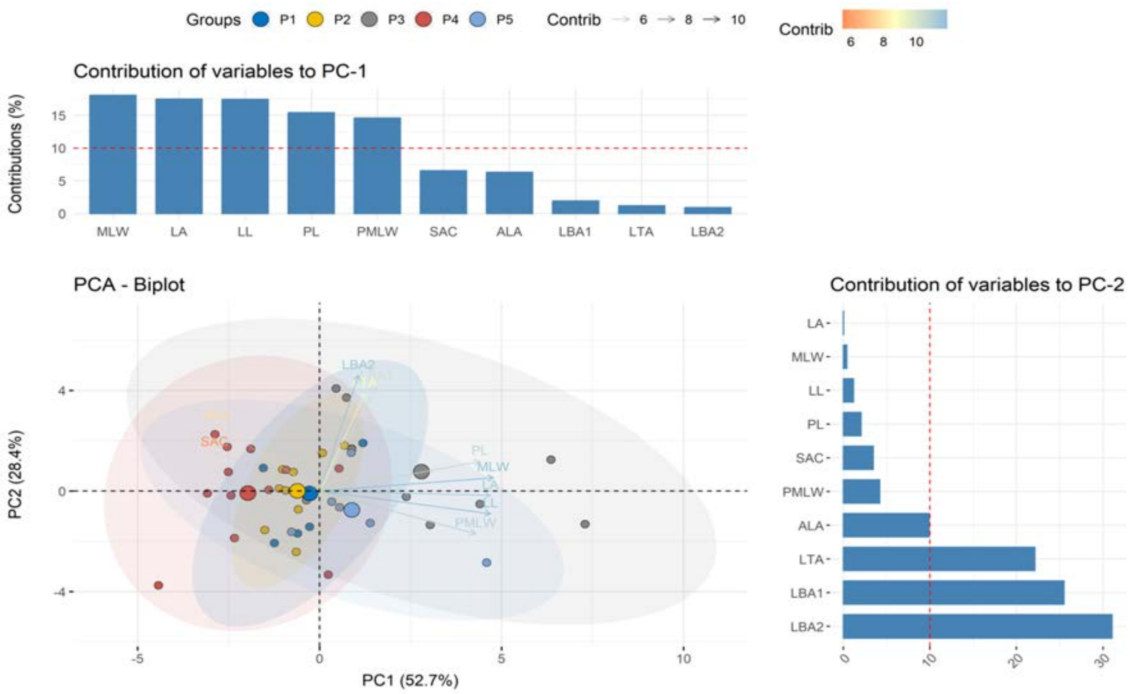

Figure 4 Principal Component Analysis (PCA) of leaf morphological traits in mountain currant (*Ribes alpinum* L.) individuals across five natural populations in the Dinaric Alps. Biplot displays individuals as coloured points based on population affiliation (as in Table 1), with ellipses outlining clustering patterns. Overlaid arrows represent direction and magnitude of morphological traits, with colour shading indicating trait contributions. Accompanying plots (above and to the right) display variable contributions to the PC variance. A red dashed reference line indicates the 10% threshold used to highlight variables with notable contribution. Trait acronyms follow definitions in Table 2.

In the k = 3 configuration (Figure 5), samples from population P3 were predominantly assigned to Cluster 1, forming a distinct group, while most individuals from P1, P2, P4, and P5 appeared in Cluster 2, with scattered assignments to Cluster 3. The k=4 solution provided finer separation (Figure 6), with P3 samples mainly grouped into Cluster 3 and P5 samples frequently into Cluster 1. Populations P1 and P2 showed dominant membership in Cluster 1 but with consistent representation in Cluster 2 as well. Notably, population P4 showed a dominant affiliation with Cluster 4, with 67% of its individuals grouped therein. Although individuals from P4 appeared across all clusters, this concentration in Cluster 4 suggests the emergence of a distinct morphological subset within the population.

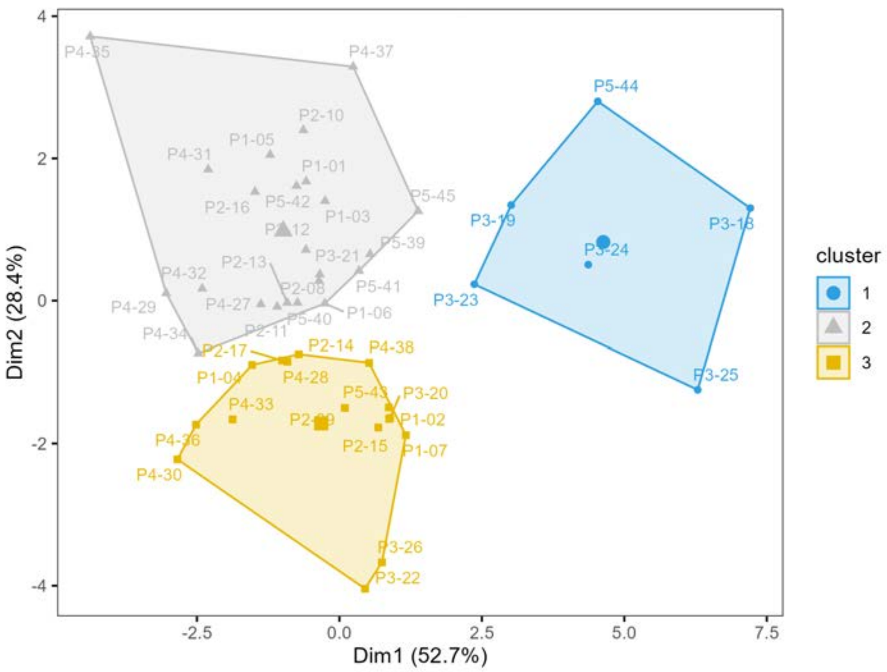

Figure 5 Factor map showing mountain currant (*Ribes alpinum* L.) individuals grouped into three clusters (k = 3) based on leaf morphological traits. Individuals are plotted as smaller symbols coloured by cluster affiliation, with larger symbols representing cluster centroids. Population labels are as in Table 1.

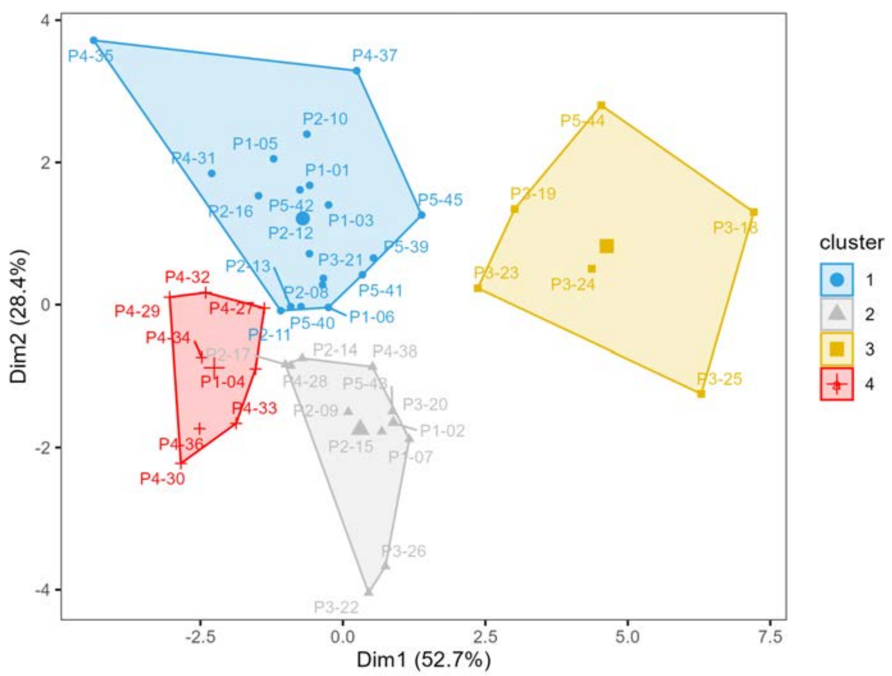

Figure 6 Factor map showing mountain currant (*Ribes alpinum* L.) individuals grouped into four clusters (k = 4) based on leaf morphological traits. Individuals are plotted as smaller symbols coloured by cluster affiliation, with larger symbols representing cluster centroids. Population labels are as in Table 1.

Redundancy analysis (RDA) revealed that environmental factors, including altitude and bioclimatic variables, were the primary drivers of leaf morphological variation in *Ribes alpinum* (Table 4). The full RDA model, which incorporated both environmental and geographic predictors, explained 45.5% of the total variation (adjusted $R^2 = 0.369$) and was statistically significant ($F = 5.2966$, $p = 0.001$). After accounting for geographic effects, the pure environmental component remained significant, explaining 19.7% of the variation (adjusted $R^2 = 0.147$, $F = 3.4439$, $p = 0.001$). In contrast, the pure geographic effect explained only 1.1% of the variation and was not statistically significant (adjusted $R^2 = -0.019$, $F = 0.3904$, $p = 0.797$). These results emphasize the predominant role of local environmental conditions – particularly temperature and elevation – in shaping leaf morphology across populations, whereas spatial position alone did not exhibit a detectable effect once environmental differences were controlled for.

Table 4 Performance metrics for full and partial RDA models assessing the effects of environmental and geographic predictors on leaf morphological variation in mountain currant (*Ribes alpinum* L.). 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	0.455	0.369	5.2966	0.001
$pRDA_{env}$	Environment | Geography	0.197	0.147	3.4439	0.001
$pRDA_{geo}$	Geography | Environment	0.011	-0.019	0.3904	0.797

The RDA ordination plot (Figure 7) provides a visual representation of the relationship between leaf morphological traits and the underlying environmental and geographic gradients. The strongest contributors to the first RDA axis (RDA1), which explains the majority of constrained variation, were BIO1 (annual mean temperature) and altitude. These variables showed high loadings on RDA1 (BIO1 = 0.798; altitude = –0.721) and were highly correlated with leaf morphology ($r^2 = 0.372$ and 0.305, respectively; $p = 0.001$), indicating that temperature and elevation are the primary environmental drivers of trait divergence in *Ribes alpinum*. Conversely, BIO9 (mean temperature of the driest quarter), BIO17 (precipitation of the driest quarter), and geographic coordinates (latitude and longitude) had low r^2 values and were not statistically significant ($p > 0.1$), suggesting minor or negligible influence on morphological variation. Loadings on RDA2 were generally lower, and none of the predictors showed strong contribution to this axis, implying that most variation is captured along RDA1.

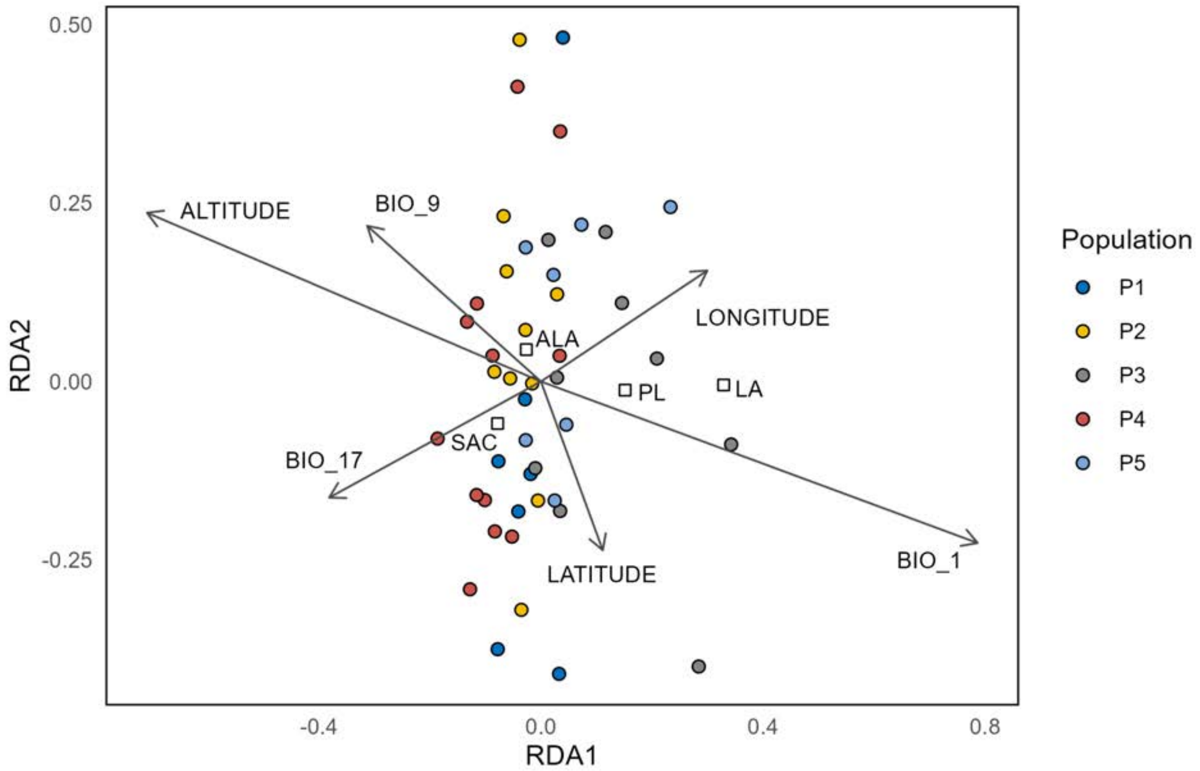

Figure 7 RDA ordination plot visualizing population–level variation in leaf morphological traits of mountain currant (*Ribes alpinum* L.) in relation to environmental and geographical gradients across five natural populations. Individuals are shown as coloured circles grouped by population (labels as in Table 1), morphological traits are displayed as square markers (acronyms as in Table 2), and environmental/geographic predictors are represented by vectors indicating direction and magnitude of association. The ordination highlights spatial and ecological structuring of trait variation.

DISCUSSION

The morphological data obtained from five natural populations of *Ribes alpinum* across the Dinaric Alps of Croatia reveal pronounced variation in leaf size and shape, underscoring the complexity of phenotypic expression within the species. This variation reflects differing degrees of developmental stability and plasticity across measured traits. Leaf dimension traits – such as length, width, and petiole length – showed moderate to high variability, suggesting that these parameters are particularly sensitive to microenvironmental influences. Notably, petiole length and total leaf area were especially variable, potentially indicating functional adjustments linked to photosynthetic optimization or mechanical support (Takenaka 1994, Filartiga et al. 2022). In contrast, shape-related traits – especially those quantifying leaf geometry – remained remarkably consistent across individuals and populations, implying structural conservatism and reduced environmental responsiveness. This contrast between size-related plasticity and geometric stability highlights the multifactorial architecture of leaf morphology, where certain traits exhibit dynamic shifts, while others are under tighter developmental or genetic control.

The analysis of morphological variability revealed significant differences among populations in seven out of ten measured traits, with leaf size parameters showing the greatest divergence. This suggests that populations of *Ribes alpinum* differ more in the overall dimensions of their leaves than in their geometric shape, pointing to a stronger influence of phenotypic plasticity in size-related traits. Among all populations, P3 (Bijele and Samarske stijene) exhibited the highest within-population variability (MDI = 4.60), likely reflecting the exceptional habitat heterogeneity of this site (Vucelić 1987, Sirovica 2025). The landscape is characterized by rocky outcrops, shallow soil pockets, and transition zones along fir–spruce forest edges. Many shrubs were found growing in these marginal microhabitats, where soil depth and moisture availability change drastically over short distances. Such spatial heterogeneity may foster plastic responses in leaf morphology, enabling individual plants to modulate their traits in response to localized environmental conditions (Körner 2003, Boucher et al. 2013, Opedal et al. 2015).

Multivariate analyses revealed clear morphological structuring among populations of *Ribes alpinum*, with PCA and k-means clustering consistently distinguishing P3 (Bijele and Samarske stijene) and P4 (Zavižan) as the most divergent groups. Although PCA showed partial overlap among individuals, the first principal component – strongly associated with leaf size traits – separated P3 and P4 along a clear gradient. P3, sampled from the lowest elevation site (1280 m), was characterized by larger leaves and formed a coherent cluster in both k = 3 and k = 4 solutions. In contrast, P4, from the highest elevation site (1608 m), exhibited markedly smaller leaves and showed dominant affiliation with Cluster 4 in the k = 4 configuration, suggesting the emergence of a distinct high-altitude morphotype. These patterns align with broader ecological findings that leaf size tends to decrease with increasing altitude due to lower temperatures, increased solar radiation, and reduced atmospheric pressure, which collectively constrain leaf expansion and favour compact morphologies for thermal and hydraulic efficiency (Körner et al. 1986, Körner 2003, Milla and Reich 2011). Whether these morphological differences stem primarily from phenotypic plasticity – flexible trait expression under environmental influence – or represent true local adaptation driven by selective pressures, remains uncertain. Phenotypic plasticity likely enables populations to modulate trait expression in response to environmental variability (Crispo 2008). However, when such plastic responses are consistently favoured across generations, they may become developmentally canalized and ultimately contribute to adaptive divergence. In reality, both mechanisms often act in tandem (Nicotra et al. 2010, Nonaka et al. 2015), and their relative contribution may vary across traits, environments, and populations.

Recent studies further suggest that phenotypic plasticity may be mediated by epigenetic mechanisms, particularly DNA methylation, which has been shown to increase in variance under stressful conditions such as elevated radiation (Nicotra et al. 2015). These epigenetic modifications can influence ecologically relevant traits without altering the underlying genetic code, providing a rapid and reversible source of phenotypic variation (Rapp and Wendel 2005, Bossdorf et al. 2008). Although direct evidence remains limited, such mechanisms may contribute to the observed morphological shifts in alpine plant populations, including *Ribes alpinum*, and enhance their capacity to persist under changing climatic conditions.

Redundancy Analysis (RDA) revealed that geographic coordinates – specifically latitude and longitude – did not significantly contribute to the observed morphological variation among populations of *Ribes alpinum*. This suggests that horizontal spatial positioning across the Dinaric Alps has limited explanatory power for leaf trait variability (Vidaković et al. 2025). In contrast, elevation-related environmental gradients – such as temperature, solar radiation, and habitat structure – emerged as the dominant factors influencing morphological differentiation. These vertical gradients shape microclimatic conditions more directly and consistently than geographic location (Körner et al. 1986, Körner 2003, 2007), especially in mountainous terrain where ecological transitions occur over short distances. The lack of correlation with geographic coordinates reinforces the idea that local environmental pressures, rather than broad spatial separation, are the main drivers of trait variation in *Ribes alpinum* across the Croatian Dinarides. Comparable findings were reported for *Dianthus sylvestris* Wulfen in the Balkan Peninsula, where environmental factors were shown to play a potentially more important role than geography in shaping morphological variability (Terlević et al. 2023).

Although our study revealed a clear elevational signal in leaf morphology, particularly in leaf size traits, it is important to note that elevation does not uniformly shape plant traits across species or even within species (de Villemereuil et al. 2018, Lampei et al. 2019, Liu et al. 2023, Vidaković et al 2025). Notably, phenotypic responses are often population-specific (Pfennigwerth et al. 2017), as illustrated in our dataset by population P5, which occupies a relatively high elevation, slightly lower than P4, yet displayed intermediate leaf sizes compared to both lower (P3) and higher (P4) elevation populations. This unexpected pattern may reflect microhabitat complexity within the sampling area: individuals from P5 occurred along a transitional ecotone between subalpine dwarf pine stands and the upper belt of beech-dominated montane forests, potentially experiencing moderate light, soil, and temperature conditions. Such ecotonal zones can buffer plants from extreme alpine stressors or lowland competition, resulting in intermediate trait expression. Similar population-specific responses have been documented in other woody taxa. For instance, Pfennigwerth et al. (2017) found that trait variation in *Rhododendron maximum* L. across elevation gradients in the Appalachian Mountains was largely driven by phenotypic plasticity, with trait–environment associations differing significantly across sites. This suggests that morphological differentiation along elevational gradients arises through a spectrum of plastic and genetic mechanisms, whose relative contributions vary among taxa, traits, and ecological settings.

Additional observations from cultivated specimens of *Ribes alpinum* grown in Croatian arboreta and botanical gardens – typically located at low elevations, slightly above 100 m a.s.l. – provide compelling evidence of the species' morphological responsiveness to environmental variation. In these lowland settings, leaves were consistently larger than those recorded in natural montane populations, often exceeding the upper range documented in our study. Moreover, cultivated plants exhibited a near-complete absence of trichomes, which are otherwise prominent on leaves from high-altitude habitats. These differences suggest that phenotypic plasticity in *Ribes alpinum* extends beyond leaf size to include surface traits, highlighting the species' capacity to modulate its morphology in response to habitat structure and elevation. These observations are further supported by data from dendrological literature, which typically reports leaf sizes ranging from 3 to 5 cm (Hegi 1961, Krüssmann 1962, Schütt 2011), in contrast to the average dimensions of approximately 2 cm recorded in our montane samples. This discrepancy likely reflects the limited ecological scope of earlier descriptions, probably based on herbarium specimens of lowland populations from the northern parts of the species' natural range, where *Ribes alpinum* is known to occur in lowland habitats (Weber 1995, Schütt 2011). In contrast, our findings, derived from *in situ* sampling across diverse high-elevation sites in the Dinaric Alps, underscore the importance of ecological context in morphological assessments and highlight the need for geographically and environmentally inclusive trait documentation.

Taken together, these results emphasize the practical significance of integrating field-based measurements with broader ecological and biogeographical perspectives. By capturing both inter- and intra-population variability, such studies not only refine species-level trait descriptions but also contribute to a deeper understanding of how environmental gradients shape plant morphology. This has implications for conservation, habitat management, and predictive modelling under changing climatic conditions, in which trait plasticity may play a key role in species resilience and adaptive potential.

CONCLUSIONS

The morphometric analysis of *Ribes alpinum* populations in the Dinaric Alps revealed substantial variation in leaf traits, primarily driven by elevation-related environmental gradients rather than geographic positioning. Leaf size traits exhibited greater variability than shape-related parameters, suggesting a strong role of phenotypic plasticity in response to local microclimatic conditions. Populations from contrasting altitudes – particularly P3 and P4 – showed clear morphological differentiation, with P3 also displaying the highest within-population diversity, likely due to its heterogeneous habitat. RDA confirmed that latitude and longitude had no significant influence on trait variation, reinforcing the importance of vertical ecological gradients in shaping plant morphology in mountainous landscapes. These findings highlight the adaptive flexibility of *Ribes alpinum* and underscore the ecological value of the Dinaric Alps as a natural setting for studying intraspecific variation and environmental adaptation.

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ASSESSMENT OF TETHERED HARVESTER PRODUCTIVITY: A CASE STUDY IN WESTERN OREGON, USA

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SUMMARY

The use of winch-assisted (tethered) mechanized harvesting systems has recently increased on steep terrain in the Pacific Northwest, USA. Tethered systems are used to support and stabilize the operation of production machines such as harvesters, feller bunchers, forwarders, and grapple skidders on steep slopes. Studies on the environmental impacts, productivity, and costs of these systems should be in focus due to the rapid use of winch-assisted systems in forestry. In this study, a tethered harvester operation working was evaluated using time and motion study analysis. The study was conducted in a clear-cutting area within a Douglas-fir stand in the Oregon Coast Range near Corvallis, Oregon, United States. The production activities were evaluated in stages, including the tethered harvester moving to the tree, preparing for cutting, cutting, and processing. The most time-consuming work stage in the study was determined to be the processing time of the tree. The average delay-free efficiency of the tethered harvester was determined as 40.16 m^3/h, while the minimum efficiency was 16 m^3/h and the maximum efficiency was 75.02 m^3/h. Production efficiency was mostly affected by tree size, with productivity increasing as tree size increased. Statistical analysis showed that there was a significant relationship between tree height, tree diameter, tree volume, and productivity.

KEY WORDS: winch-assisted harvesting systems, steep terrain, tethered harvester, time and motion study, productivity, Pacific Northwest, USA

INTRODUCTION

Mechanized timber harvesting operations are conducted in most forested regions (Long et al. 2002, Wang et al. 2004, Visser and Spinelli 2012, Hiesl and Benjamin 2013, Chung et al. 2022). Mechanized harvesting vehicles, such as harvesters and feller bunchers, are used during the cutting stage, while skidders, forwarders, and skylines are utilized for timber extraction (Gülci et al. 2021). However, since mechanical harvesting vehicles are efficient in areas where the terrain slope is less than 30%, their safe use in mountainous regions with steeper slopes has been limited (Gülci et al. 2021, Pokharel et al. 2023). All known mobility criteria and restrictions for forest vehicles are mainly concerned with their ability to move uphill (Poršinsky et al. 2023). For this reason, innovative mechanical harvesting systems integrated with cable winches have been increasingly used in the mountainous terrain of the United States in recent years (Acuna et al. 2011, Holzfeind et al. 2020, Green et al. 2020, Chung et al. 2022, Pokharel et al. 2023).

Winch-assisted harvesting is called tethered or cable-assisted. Tethered harvesting systems use cable winch systems on harvesters, feller bunchers, forwarders, loaders, and skidders to stabilize and support equipment operations on steep slopes. Harvesting machines are secured with cable connections, ensuring safe operation on steep terrain (Sessions et al. 2017, Pokharel et al. 2023). The system is specifically designed to increase machine mobility and reduce wheel or track slippage (Holzfeind et al. 2020, Chung et al. 2022). In this system, the machine

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can go up and down a steep slope with the help of a winch (Sessions et al. 2017, Pokharel et al. 2023). This winch system is either mounted directly on the working equipment or placed on another piece of equipment to serve as a fixed base (Holzfeind et al. 2020, Pokharel et al. 2023).

Tethered harvesting systems provide significant advantages such as enhancing operator safety, replacing dangerous manual felling, reducing negative impacts on the soil, and improving productivity for forwarding, skidding, or yarding operations (Green et al. 2020, Holzfeind et al. 2020). The cable system enables equipment to operate on slopes that would typically be considered hazardous for the equipment or harmful to the soil. Thus, the cable system enhances the stability of equipment on steep or unstable terrain and improves traction on gentler slopes (USDA 2024).

The productivity of harvesting increases with the tethered system because trees are cut, bucked, and bunched in a short time with mechanical harvesting systems (Green et al. 2020). These systems reduce costs from the first stage of production to loading onto the truck (Chung et al. 2022). Studies conducted in both the US and worldwide indicate that salvage logging has lower productivity and higher costs than harvesting undamaged stands (Conrad and Joseph 2023). Tethered systems can be more efficient compared to traditional methods, such as chainsaws used on steep slopes (Gülci et al. 2016, Chung et al. 2022).

The tethered harvesting system was first developed in Europe in the early 2000s and then began to be extensively developed in New Zealand in the mid-2000s, after which Chile began to adopt this technology (Belart et al. 2019, Holzfeind et al. 2020). Subsequently, in the early 2010s, it was adopted by the forestry industry in the Pacific Northwest of the United States (Acuna et al. 2011, Green et al. 2020, Holzfeind et al. 2020, Chung et al. 2022, Pokharel et al. 2023). Today, in Central Europe, Canada, and the Pacific Northwest of the United States, cable-assisted systems are widely used due to steep terrain and low environmental impact (Garren et al. 2019). However, only a few studies have been conducted on the productivity of these new harvesting systems. In this study, time study techniques were applied to estimate the productivity of harvesting with a tethered harvester.

MATERIALS AND METHODS

Study area

The study was carried out in the Oregon Coast Range of western Oregon, United States (123.605833 W, 44.320278 N), where the average terrain slope is 60% (Figure 1). The study was carried out in a Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco var. *menziesii*) stand damaged by the ice storm that occurred in mid-January 2024. The operation was done to recover value from the damaged trees and to permit prompt reforestation.

Field study

In this study, measurements were carried out with a tethered harvester. The field study was conducted using a 2021 model 260 kW Ponsse Bear harvester. Harvesting operations were observed from the operator's cabin

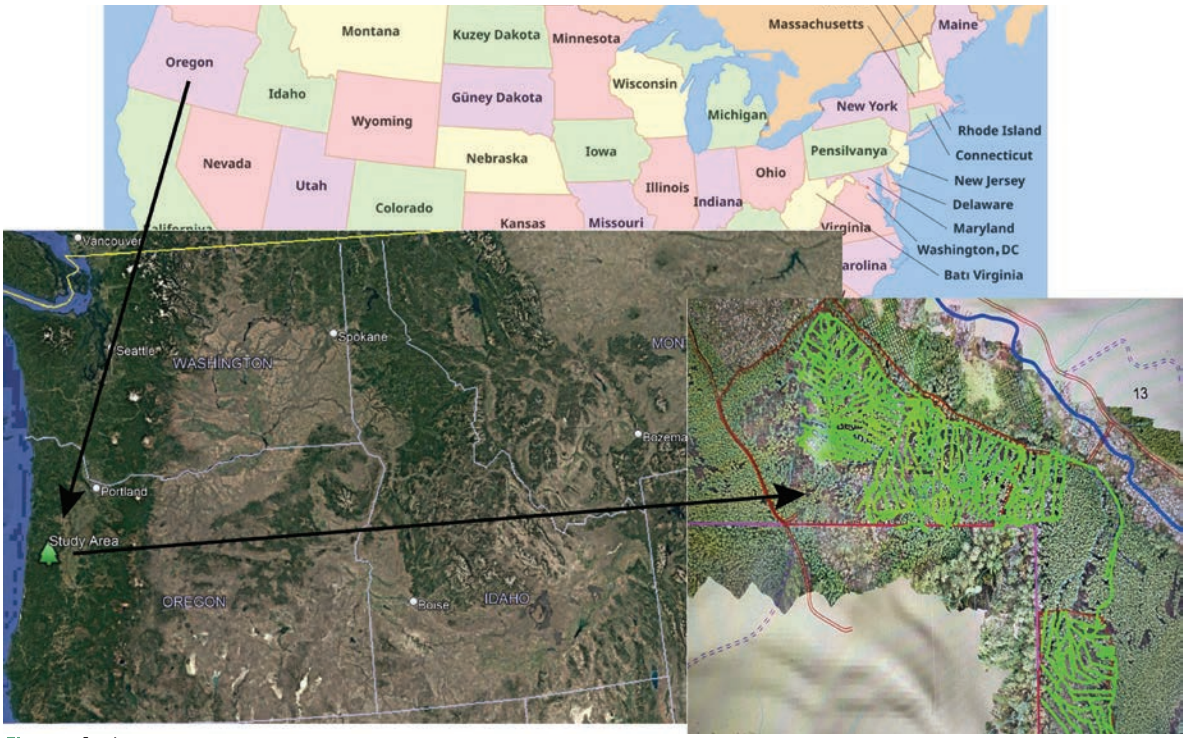

Figure 1 Study area.

Figure 2 Tethered harvester (up), observation from inside the operator cabin (down).

Table 1 Technical specifications of tethered harvester.

Dimensions	
Minimum weight (kg)	23800
Typical weight (kg)	24500
Length (m)	8.99
Width (m)	2.9-3.1
Ground clearance (m)	0.7
Transportation height (m)	3.88
Crane	
Tilt angle	±20°
Turning angle	250°
Crane reach (m)	8.6-10
Engine	
Engine power	260 kW
Tractive force	230 kN
Hydraulic system	
Control system	Ponsse OptiControl
Hydraulic circuits	Separate
Crane pump (cm^3)	190
Harvester head pump (cm^3)	190
Harvester heads	
Minimum weight (kg)	1450
Feed system	3 feed rollers
Feed force (kN)	36
Maximum opening (cm)	74
Feeding speed (m/s)	4.5

(Figure 2). The technical specifications of the harvester are given in Table 1.

All work stages of harvesting were recorded with a mobile phone camera. After the field studies, the time data were transferred to Excel. All information was automatically recorded in the on-board computer during the operator's working time. Certain information (tree diameter, tree height and volume) about this harvesting was obtained from the vehicle records.

The work cycle of a tethered harvester includes move (movement between trees), cut preparation (started when the boom started moving), fell and process (started with cutting for felling), and bunch (sorting felled and processed trees into decks) (Figure 3). In this study, a direct observation was conducted solely for the measurement of efficient basic working time. No delays were experienced due to vehicle breakdowns or other reasons. Therefore, delay time has not been considered. The trees that were cut and processed with a tethered harvester were removed from the field using a forwarder.

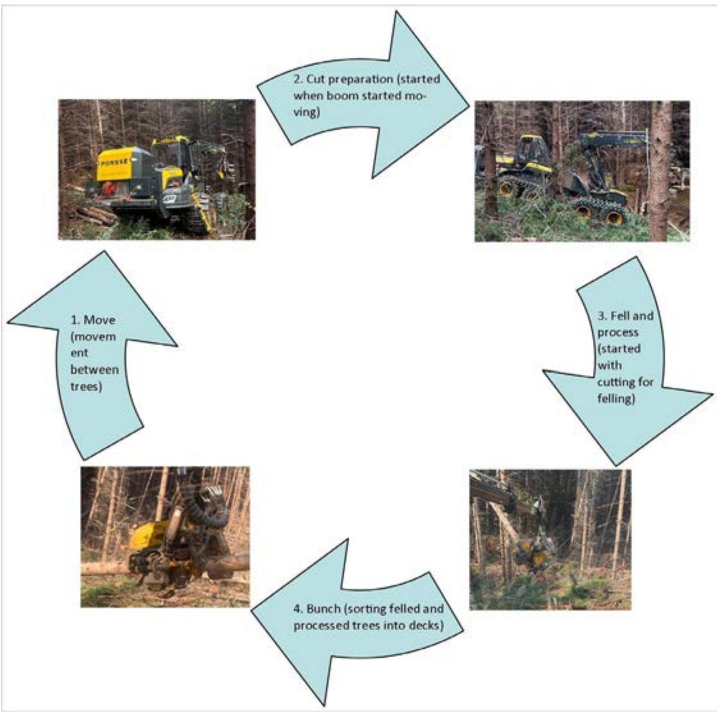

Figure 3 Tethered harvester work cycle.

Table 2 Descriptive statistics for field measurement and productivity.

	Height (m)	DBH (cm)	Volume (m^3)	Moving (s)	Preparing (s)	Cutting (s)	Processing (s)	Total (s)	Productivity (m^3/h)
N	60	60	60	60	60	60	60	60	60
Mean	17.98	18.78	0.29	3.90	2.72	1.43	16.05	24.10	40.16
STD.	3.67	4.53	0.16	1.09	0.80	0.50	4.06	4.54	16.87
Min.	10.00	12.00	0.08	2.00	1.00	1.00	9.00	17.00	16.00
Max.	25.00	26.00	0.65	6.00	5.00	2.00	25.00	31.00	75.02

Statistics

Initially, basic mean and standard deviation values were calculated and visualized using SPSS and the Rstudio (R Core Team 2018). The Pearson correlation test was then applied to examine the relationships between specific factors—tree height (X_1), DBH (X_2), and volume (X_3)—and the productivity (Y) of the tethered harvesting operation.

In this study, multiple linear regression analysis was used to develop mathematical models for predicting tethered harvester productivity in cut-to-length harvesting. Initially, a multiple linear regression model was applied to assess the relationships between tree height, DBH, volume, and productivity. Diagnostic plots were used to evaluate model fit. The residuals vs. fitted plot, Q-Q plot, and scale-location plot were considered for models, while Cook's distance was analyzed to detect influential observations that could potentially affect the model's performance.

Initially, we applied a log-transformed polynomial regression model to improve consistency and predictive accuracy. Due to preliminary diagnostic assessments, which indicated possible non-linearity and heteroscedasticity (non-constant variance) in the residuals, this transformation was applied for further analysis. The polynomial transformation helped us to understand the relationships between the predictors and productivity. Logarithmic transformation by skewed data into a more normal distribution stabilized the variance and improved model interpretability.

Outliers and disturbance points, which could have adversely affected model accuracy, were detected. Outliers were removed from the model. The prediction model was re-established to ensure reliability of the model. Metrics such as R2, adjusted R2, root mean square error (RMSE) and mean absolute error (MAE) were used as the success indicator of both the linear and polynomial models. Besides, Variance Inflation Factor (VIF) values were used to assess multicollinearity. In this study, R packages, including "psych", "broom", "tidyverse", "mass" and "ggplot2" (Venables and Ripley 2002, Wickham 2009, Van den Boogaart and Tolosana-Delgado 2013, Revelle 2017, Wickham et al. 2019, Robinson et al. 2024) were used in RStudio environment.

RESULTS

In this study, data from 60 trees was collected. The average tree height, diameter and volume were 17.98 m, 18.78 cm and 0.29 m^3, respectively. During harvesting, the time values of the work stages (moving towards the tree, preparing to cut, cutting, and processing) were calculated for the 260 kW Ponsse Bear model tethered harvester. According to the descriptive statistics results, the work stages that took the most time were processing,

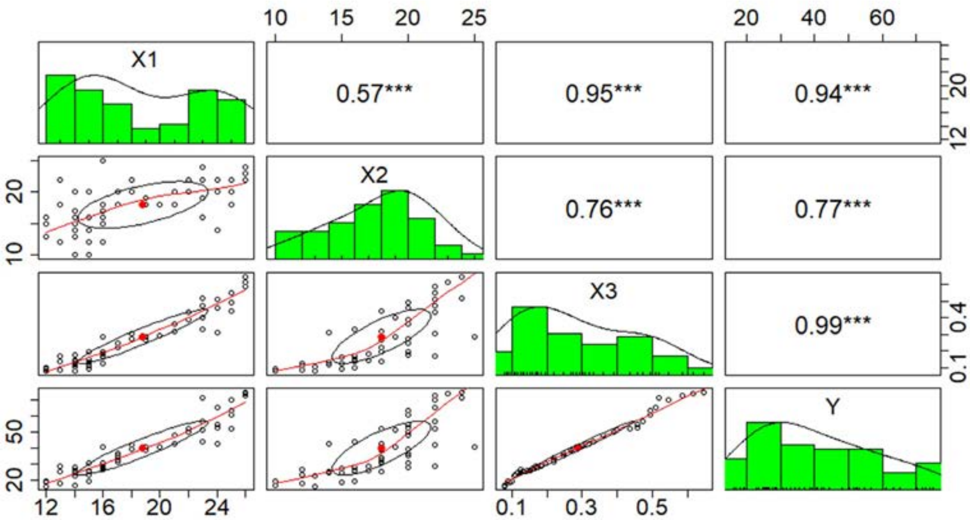

Figure 4 The Pearson r correlations (significance levels are *: 0.05 and ***: 0.001).

averaging 16.05 seconds, followed by the moving stage with an average of 3.90 seconds. The phase that took the least time was cutting, with an average of 1.43 seconds (Table 2).

The correlation between height, DBH, and volume with productivity was determined using the Pearson correlation test. A strong positive relationship was found between productivity and tree height (X_1) (r = 0.76), DBH (X_2) (r = 0.94), and volume (X_3) (r = 0.99) (Figure 4).

The analysis involved comparing a multiple linear regression model and a log-transformed polynomial regression model to evaluate their effectiveness in predicting the dependent variable (productivity) based on predictors X_1, X_2, and X_3. Both models showed high R^2 values, indicating that a substantial amount of variance in the dependent variable was explained by the predictors. However, the models differed in terms of fit quality, residual distribution, coefficient significance, and multicollinearity concerns, providing insights into which approach might be more suitable for capturing the underlying relationships in the data.

The multiple linear regression model exhibited a high R^2 value of 0.986, with an adjusted R^2 of 0.985, suggesting that it captures most of the variation in the dependent variable. The residual standard error was 2.061, and the performance metrics were acceptable. However, the vresiduals displayed considerable spread, with a minimum of -4.43 m^3/h and a maximum of 7.44 m^3/h. This range indicates potential variability in how well the model fits different data points, especially outliers or observations with higher leverage.

The calculation of MSE, RMSE, and MAE resulted in acceptable range values. However, in terms of the significance of coefficients, only X_3 was statistically significant ($p < 0.001$), while X_1 and X_2 had high *p*-values, indicating non-significant effects. This lack of significance could be due to multicollinearity, as evidenced by the high Variance Inflation Factor (VIF) values, particularly for X_1 and X_3, suggesting severe multicollinearity, which can inflate standard errors and obscure the true relationship between predictors and the dependent variable. The presence of multicollinearity could also be responsible for the high standard error associated with the estimates, reducing the interpretability of the coefficients (Table 3).

Table 3 Parameters of multiple linear regression model for productivity.

	Model 1	Performance and VIF* values	
Intercept	10.229	R^2	0.986
Height (X_1)	-0.086	AdjR^2	0.985
Height² (X_1^2)		RMSE	1.990
DBH (X_2)	0.085	MAE	1.426
DBH² (X_2^2)		MSE	3.964
Volume (X_3)	104.215	Height*	21.746
Volume² (X_3^2)		DBH*	5.149
		Volume*	34.796

* Variance Inflation Factor (VIF)

The residual plots for the linear model indicated some heteroscedasticity, with a pattern in the residuals vs. fitted plot suggesting that residuals might increase with fitted values. Additionally, the normal Q-Q plot showed deviations from normality in the tails, suggesting the presence of outliers or influential points. These issues imply that the linear model might not fully satisfy the assumptions required for a reliable linear regression model, particularly in terms of homoscedasticity and

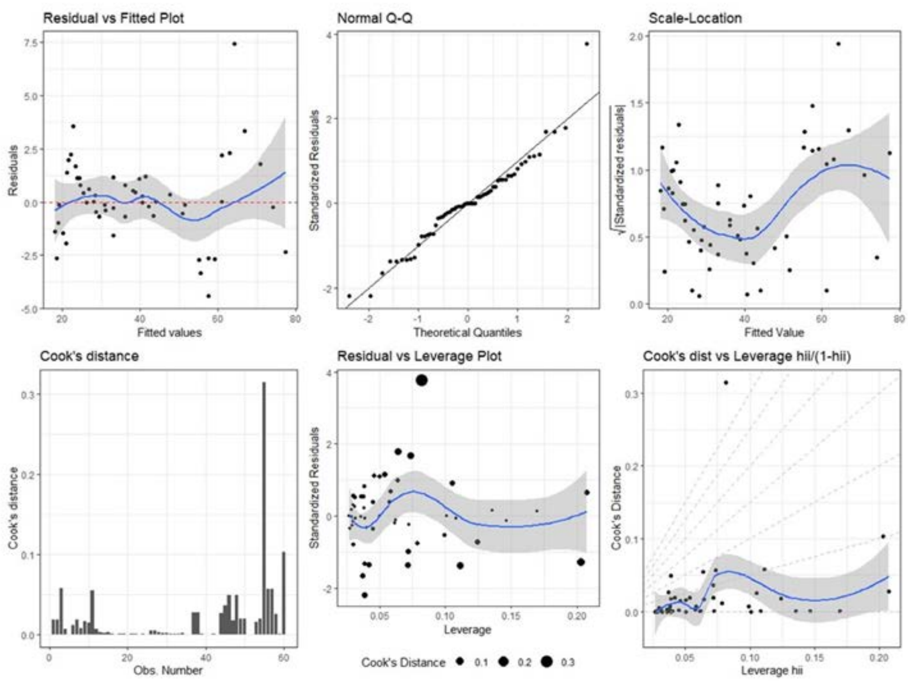

Figure 5 Diagnostic plots of the linear model.

normality of residuals. The lack of fit indicated in Figure 5 is because the linear model cannot adequately explain the intricacies of the given data.

A log-transformed polynomial regression model produced more successful and reliable results. Polynomial terms were suitable for non-linear relationships between the predictors and the dependent variable. The log transformation reduced heteroscedasticity, while the polynomial terms allowed for a more flexible fit. The resulting model showed a slight improvement in R^2 and adjusted R^2, suggesting that the polynomial transformation provided a marginally better fit than the linear model. The residuals had a tighter distribution, ranging from -0.107 m^3/h to 0.125 m^3/h, indicating a more consistent fit across observations. The smaller residual range and improved residual metrics suggest that the polynomial model captures the data points more accurately, reducing the influence of outliers and high-leverage points compared to the linear model.

Considering the linear regression model, the residual standard error for the polynomial model decreased to 0.0516, and the performance metrics showed slight improvements with MSE, RMSE, and MAE. The log-transformed polynomial model shows a significant reduction in VIF values compared to the linear model, especially for X_1 and X_3. In the linear model, X_1 and X_3 have high VIFs of 21.746 and 34.796, respectively (Table 3), indicating strong multicollinearity. In contrast, after transforming to a polynomial form and using log-transformation, poly(X_1^2) and poly(X_2^2) have much lower adjusted VIF values (2.724 and 1.879), suggesting reduced multicollinearity in the polynomial model. For X_3, the VIF also decreases to 9.269, though it remains relatively high compared to the other predictors in the polynomial model (Table 4).

Table 4 Parameters of the log-transformed polynomial regression model for productivity.

	Model 2	Performance and VIF* values	
Intercept	3.431	R^2	0.986
Height (X_1)	1.820	AdjR^2	0.985
Height² (X_1^2)	-0.216	RMSE	1.976
DBH (X_2)	1.051	MAE	1.456
DBH² (X_2^2)	-0.08	MSE	3.904
Volume (X_3)	0.594	Height*	2.724
Volume² (X_3^2)		DBH*	1.879
		Volume*	9.269

* Variance Inflation Factor (VIF)

The residuals appear more randomly scattered around the horizontal line with minimal patterns, indicating an improved fit compared to the linear model. Diagnostic plots were implemented to explain and compare the results in the linear model (Figure 6).

The polynomial terms seem to address some of the non-linearity observed in the linear model. According to normal Q-Q plots, the residuals for the polynomial model align more closely with the 45-degree line,

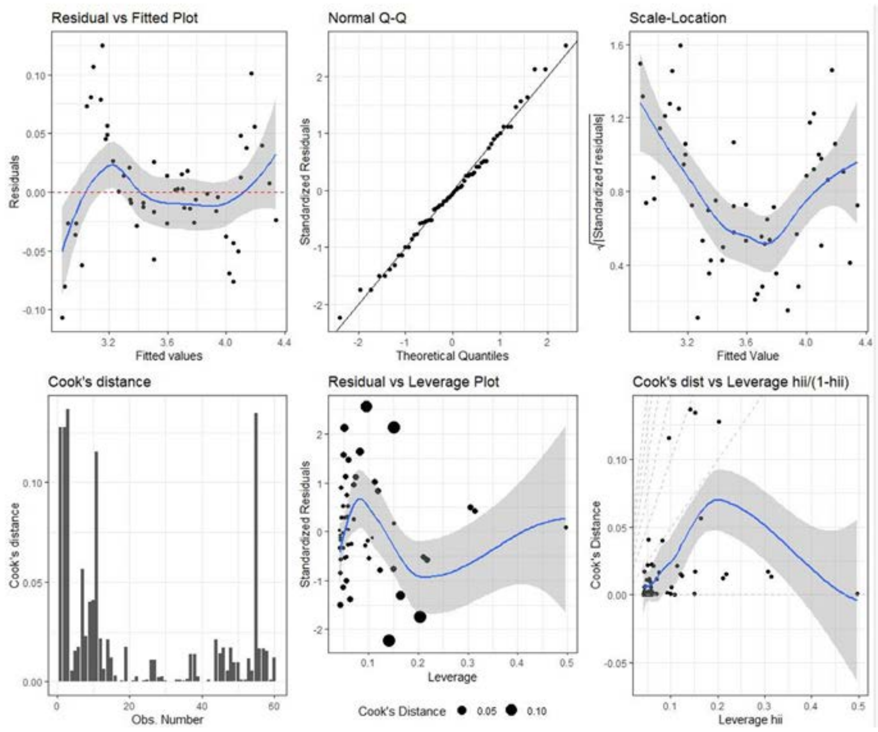

Figure 6 Diagnostic plot of the polynomial model.

though slight deviations may still occur at the tails. This alignment suggests an improvement in the normality of residuals, despite some deviations indicating minor issues with normality. The blue line in the polynomial model scale-location plot is relatively horizontal, with a more consistent spread of residuals along the fitted values. This suggests that heteroscedasticity has been reduced, meaning that the polynomial transformation helped to stabilize the variance. In this plot, there are fewer points with high Cook's distances compared to the linear model. Observations previously identified as influential have reduced impact, showing that the polynomial model is less sensitive to these points. The polynomial model shows fewer points with both high leverage and large residuals, reducing the overall influence of outliers. Observation 55, flagged in the linear model, appears less problematic here, showing that the polynomial model accommodates these data points better. Similar to the residuals vs leverage plot, fewer points have both high leverage and Cook's distance, indicating that influential observations exert less control over the model's results.

DISCUSSION

In this study, our results indicated that the average operation productivity of the tethered harvester was calculated as 40.16 m^3/h, while the minimum efficiency was 16 m^3/h and the maximum efficiency was 75.02 m^3/h. This variation is related to tree dimensions, including diameter, height, and volume. In general, our results showed slight difference considering previous studies on tethered harvesting productivity. This case study showed higher productivity than the untethered harvesting studies. For example, Tufts (1997) calculated productivity by using untethered Ponsse HS-15 harvester, which ranged from 8.8 to 65.2 m^3 per productive machine hour (PMH). Jiroušek et al. (2007) conducted a study where productivity of a harvester ranged from 13.5 m^3/h to 60.5 m^3/h with a fairly large stem size (0.1 m^3 to 1.0 m^3). Bilici and Abbas (2018) conducted a study on the productivity of untethered harvesting in a clear-cutting operation by using single-grip harvester in Brutian pine stands. Productivity of the harvesting operation was found to be 24 m^3/h, ranging between 6 m^3/h and 57 m^3/h. Baek (2018) calculated productivity for harvesting ranging from 28.8 to 35.6 m^3 per productive machine hour (PMH). Apafaian et al. (2017) observed 26.5 m^3/PMH for 0.36 m^3 per stem in a Norway spruce clear-cutting. Ghaffariyan et al. (2013) observed that the productivity of the harvester was 56.7 m^3/h. However, Green et al. (2020), whose study showed higher productivity than our study, found machine productivity which ranged from 28.75 to 92.36 m^3 per scheduled machine hour. Differences between previous studies may include variations between operators, differences in silvicultural prescriptions, and more advanced technologies in newer equipment.

In this study, statistical analyses revealed that the productivity of the tethered harvester varied according to tree height, DBH, and volume. According to the results, as tree size increased, productivity also increased. Similar studies have shown that productivity increases with the increase in tree size (Kellogg and Bettinger 1994, Tufts 1997, Wang et al. 2004, Nurminen et al. 2006, Bilici and Abbas 2018, Gülci et al. 2021, Pokharel et al. 2023).

The work stage that took the most time in this study was the processing stage (Table 2). Comparing our results with previous studies on tethered or untethered harvesting, the processing stage consumes more time than the other work stages (Kellogg and Bettinger 1994, Tufts 1997, Nurminen et al. 2006, Bilici and Abbas 2018). The size of felled trees directly affected the stage of processing (Suadicani and Fjeld 2001, Wang and Haarlaa 2002, Bilici and Abbas 2018).

The polynomial model proved to be more effective for non-linear patterns. In other words, polynomial model presented a better choice when the relationship between variables is not purely linear. In forestry operations, factors like DBH and height can have a non-linear effect on productivity (Ackerman et al. 2024). Normality of data, which is essential for a valid parametric analysis, can be provided by performing polynomial models (Gülci et al. 2021). As a result, the log-transformed polynomial regression model provided a better fit to the data rather than the multiple linear regression model. On the other hand, the log transformation reduced heteroscedasticity, and showed that the residuals are more consistent. Additionally, the log-transformed polynomial model appears to address multicollinearity issues better, especially for X_1 and X_3, making it a potentially more reliable model for interpreting the effects of these predictors on productivity (Tables 3 and 4). Polynomial terms allow an improved capture of the nonlinear relationship between the two variables and a better fulfillment of certain parametric assumptions such as normality, homoscedasticity, and insensitivity to influential points (Gülci et al. 2021). Both these models, however, appear to show minor deviations from normality; hence, further transformations may be considered if strict normality is required.

The polynomial model satisfies the homoscedasticity assumption and it is more acceptable and much more effective for reliable parametric regression analysis in this study. The reduced heteroscedasticity indicates that the polynomial model error terms have more constant variance, improving model efficiency. The polynomial model's reduced sensitivity to influential points makes it a more robust choice for parametric analysis, where outlier influence can skew results. Also, the polynomial model better handles leverage and influential points, making it a more effective choice in parametric modeling by providing a fit less susceptible to skewing by outliers.

CONCLUSIONS

In this case study, production operations with a tethered harvester were examined in terms of productivity in a Douglas-fir stand damaged by just one ice storm in western Oregon. The results showed that the average productivity of the tethered harvester operating were 40 m^3/h. The results also indicated that tree dimensions (diameter, height, and volume) affected the productivity of the tethered harvester.

The productivity of the tethered harvester's harvesting equipment can be analyzed using polynomial regression, because the polynomial regression model provided a more effective fit than the linear model for analyzing productivity in tethered harvester operations. Considering metrics and ability to handle non-linear patterns, the log-transformed polynomial regression model was chosen as the suitable approach for this data set. In the future, concentration on the model should be made with regard to the problem of multicollinearity. For example, when considering advanced techniques of data standardization or further exploration of other variable transformation methods, reliability could be further improved. Additionally, robust regression methods could be considered to further mitigate the impact of influential points and enhance model stability. In summary, the log-transformed polynomial model provides a more accurate and nuanced fit, but multicollinearity remains a key area for improvement.

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Stručni rad – Professional papers
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PROSTORNA POKRIVENOST NATURA 2000 ŠUMSKIH CILJNIH STANIŠNIH TIPOVA U ZADARSKOJ ŽUPANIJI

SPATIAL COVERAGE OF NATURA 2000 FOREST TARGET HABITAT TYPES IN ZADAR COUNTY

Zoran ŠIKIĆ[1]*, Morana BAČIĆ[2]

SAŽETAK

U Zadarskoj županiji nalazimo tri šumska ciljna stanišna tipa (CST) u tri biogeografske regije od kojih je jedan prioritetni stanišni tip. Prostorne analize obavezno su polazište i sastavni dio pripremnih radova za kvalitetno planiranje i upravljanje područjima ekološke mreže Natura 2000 te su stoga odabrane kao svrha ovoga istraživanja. Pomoću metode „Geoprocessing" u ArcGIS-u kreirane su nove vrijednosti s ciljem izračuna površina šumskih CST u područjima ekološke mreže u Zadarskoj županiji. Korištenjem alata GIS (Geografskog informacijskog sustava) prikupljeni su podaci koji pokazuju da se šumski CST u Zadarskoj županiji nalaze na 6.849,56 ha, što čini 5,55 % kopnenog dijela Natura 2000 područja očuvanja značajnih za vrste i stanišne tipove (POVS), odnosno 1,88 % kopnenog dijela županije. Opće stanje šumskih ciljnih stanišnih tipova na području Zadarske županije ocijenjeno je kao dobro, vrlo dobro i izvrsno. Rizik od požara je visok, a značajnu ugrozu predstavljaju i klimatske promjene. Nužna je uspostava sustavnog praćenja stanja šumskih ciljnih stanišnih tipova. Rezultati ovog istraživanja mogu se koristiti kao polazište za daljnje studije i planiranje očuvanja prirodnih staništa unutar ekološke mreže Natura 2000 u Zadarskoj županiji.

KLJUČNE RIJEČI: ekološka mreža Natura 2000, prostorne analize, šumski stanišni tip, Zadarska županija

UVOD
INTRODUCTION

Prema Zakonu o zaštiti prirode (NN 80/13, 15/18, 14/19) stanište je jedinstvena prostorna funkcionalna jedinica ekosustava, geografski precizno određena, sa specifičnim biotičkim i abiotičkim svojstvima. Sva istovrsna staništa čine isti stanišni tip. Treba istaknuti da je općeprihvaćeni cilj očuvanja bioraznolikosti očuvanje stanišnih tipova u povoljnom stanju, što podrazumijeva da je prirodno područje rasprostranjenja i površina koju pokriva stabilna ili se povećava. Osim tog kvantitativnog elementa u konačnici je bitan i onaj kvalitativni koji podrazumijeva održavanje specifične strukture i funkcije stanišnog tipa koje su nužne za njegov dugoročni opstanak, a koje su ujedno i preduvjet za očuvanje značajnih vrsta tog stanišnog tipa u povoljnom stanju. Stanišni tipovi se sukladno Pravilniku o popisu stanišnih tipova i karti staništa (NN 27/21) dokumentiraju Kartom staništa u digitalnom obliku kao slojem Geografskog informacijskog sustava (GIS) o rasprostranjenosti pojedinih stanišnih tipova na teritoriju Republike Hrvatske (RH), a javno su dostupni putem mrežnog portala Informacijskog sustava zaštite prirode (Bioportal 2025) kojeg

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vodi ministarstvo nadležno za zaštitu prirode. Prema Nacionalnoj klasifikaciji staništa (5. verzija) (NKS 2018) šumska staništa su ona na kojima se nalazi cjelokupna šumska vegetacija, gospodarena ili negospodarena, prirodna ili antropogena (uključujući i šumske kulture), zajedno s onim razvojnim stadijima koji se po flornom sastavu ne razlikuju od stadija zrelih šuma.

Prema Zakonu o zaštiti prirode (NN 80/13, 15/18, 14/19), ekološka mreža Natura 2000 je koherentna europska ekološka mreža prirodnih stanišnih tipova i staništa divljih vrsta od interesa za Europsku uniju koja omogućuje čuvanje ili, ukoliko je potrebno, povrat u povoljno stanje očuvanja u prirodnom području rasprostranjenosti. Čine je područja očuvanja značajna za ptice – POP te područja očuvanja značajna za vrste i stanišne tipove – POVS. Značajan udio zdravih ekosustava u Europi nalazi se u mreži Natura 2000. Prema najnovijim istraživanjima Europske komisije procjenjuje se da će koristi koje proizlaze upravo iz područja u mreži Natura 2000 biti u rasponu od 200 do 300 milijardi eura godišnje. Sama ukupna vrijednost ugljika u staništima mreže Natura 2000 znatno je veća, a među njima šumska staništa u mreži Natura 2000 sadržavaju najveću količinu ugljika, u vrijednosti od 318,3 do 610,1 milijardi eura (EK 2010). Ciljni stanišni tipovi (u daljnjem tekstu CST) jesu ona staništa unutar europskog državnog područja država članica kojima prijeti nestanak unutar njihova prirodnog areala. Staništa koja imaju mali prirodni areal zbog regresije, kojima je područje u prirodi samo po sebi ograničeno ili koja su izvanredni primjeri staništa s tipičnim karakteristikama jedne ili više biogeografskih regija također su CST i kao takvi navedeni su u Prilogu I. Direktive o staništima (Ured za publikacije Europske unije 2018). Prioritetni stanišni tipovi su prirodni stanišni tipovi kojima prijeti opasnost nestajanja, a koji su prisutni na europskom području država članica i za čije je očuvanje posebno odgovorna Europska unija. Takvi stanišni tipovi označeni su zvjezdicom (*) u Prilogu I. Direktive o staništima. U Izvješću iz 2013. Ruralni razvoj u EU-u – statistički i gospodarski podaci, procijenjeni su postoci šuma u mreži Natura 2000 upotrebom podataka Corine Land Cover, što ujedno znači da se ne poklapaju sva šumska područja sa stanišnim tipovima navedenima u Prilogu I. Direktive. Ta procjena pokazuje da se polovina mreže Natura 2000 sastoji od šuma, no sa znatnim razlikama između država i biogeografskih regija. EU pokriva devet biogeografskih regija koje su svaka za sebe karakteristične po vegetaciji, klimi, topografiji i geologiji. Granice regija nisu fiksne, no omogućavaju praćenje trendova očuvanja vrsta i staništa u sličnim uvjetima diljem Europe ne obraćajući pažnju na državne granice. Tih devet regija su: alpska, kontinentalna, mediteranska, panonska, borealna, atlantska, crnomorska, stepska i makaronezijska, od kojih Hrvatska obuhvaća prve tri (MZOZT, HAOP 2025). Površinski udio šuma koje su dio mreže Natura 2000 iznosi od 6,4 % u Ujedinjenoj Kraljevini (UK – sada bivšoj članici EU) do 53,1 % u Bugarskoj, a to se stanje po pitanju Nature 2000 značajnije ne mijenja bez obzira na to što je izvor iz 2010. godine (Europska agencija za okoliš 2010).

Zadarska županija je središnje položena hrvatska obalna regija koja obuhvaća geografski profil od otoka, priobalja, ravnokotarskoga i bukovičkog zaobalja, velebitskoga prostora do ličko-pounskog prostora. To je prostor velike geomorfološke razvedenosti i najvećim dijelom umjereno tople vlažne klime (s pretežito suhim i vrućim ljetima) te dijelom šumsko-snježne klime u visinski istaknutijim predjelima (Plan razvoja Zadarske županije 2021. – 2027. (Plan razvoja 2021–2027)) Zadarska županija površinom je jedna od većih (3.643,33 km^2 ili 6,4 % površine države) te je jedna od najraznolikijih županija u RH. Županiji pripada i oko 3.632,9 km^2 morske površine Jadrana što čini 12 % hrvatskog mora (PPZDŽ 2001).

Na području Zadarske županije nalazi se 91 POVS područje ekološke mreže na površini od 189.176,30 ha od kojih se 123.188,52 ha odnosi na kopneni dio Županije. Republika Hrvatska pod Naturom 2000 (POP + POVS) ima 36,67 % kopnene površine (MINGOR 2019), odnosno 745 POVS područja prekrivaju 28,41 % kopna (MINGOR 2019), dok u Zadarskoj županiji taj postotak iznosi 33,85 %.

Svrha ovoga istraživanja je prostorna analiza istraživanog područja koja je obavezno polazište i sastavni dio pripremnih radova za kvalitetno planiranje i upravljanje područjima ekološke mreže Natura 2000 u Zadarskoj županiji. Temeljem rasprostranjenosti ciljnih stanišnih tipova određuju se upravljačke zonacije koje posljedično određuju i mjere zaštite i očuvanja te uvjete održivog korištenja prirodnih dobara, što šumska staništa i šume svakako jesu.

MATERIJALI I METODE

MATERIALS AND METHODS

Za potrebe istraživanja prostorne pokrivenosti šumskih ciljnih stanišnih tipova (CST) u područjima ekološke mreže Natura 2000 u Zadarskoj županiji provedene su prostorne analize korištenjem softverskog paketa ArcGIS Desktop verzije 10.8.1 (ESRI). Zavod za zaštitu prirode Republike Slovenije je za zonaciju Natura 2000 područja koristio programa GIS ArcView 8.3 kojim su se podaci preklapali i analizirali s podacima različitih digitalnih baza, poput podataka o korištenju zemljišta, poplavnim područjima, nadmorskoj visini, geološkoj podlozi te postojećim podacima o kartiranju stanišnih tipova (Petkovšek 2007). Analize su obuhvatile sljedeće korake:

Prikupljanje podataka - *Data colection*

Korištena su tri službena izvora podataka u HTRS96/TM projekciji:

a) Geoportal (2025), Državna geodetska uprava: Kartografske podloge i podaci o administrativnim granicama preuzeti su putem WMS (Web Map Service) usluge u formatu .shp poligona.

b) Bioportal (2025), Informacijski sustav za zaštitu prirode: Podaci o granicama Natura 2000 područja očuvanja značajnih za vrste i stanišne tipove (POVS) preuzeti su putem WFS (Web Feature Service) usluge.

c) Ministarstvo zaštite okoliša i zelene tranzicije: Službeni podaci o rasprostranjenosti šumskih CST, izrađeni za potrebe Planova upravljanja (MINGOR 2021).

Prostorne analize - *Spatial analyses*

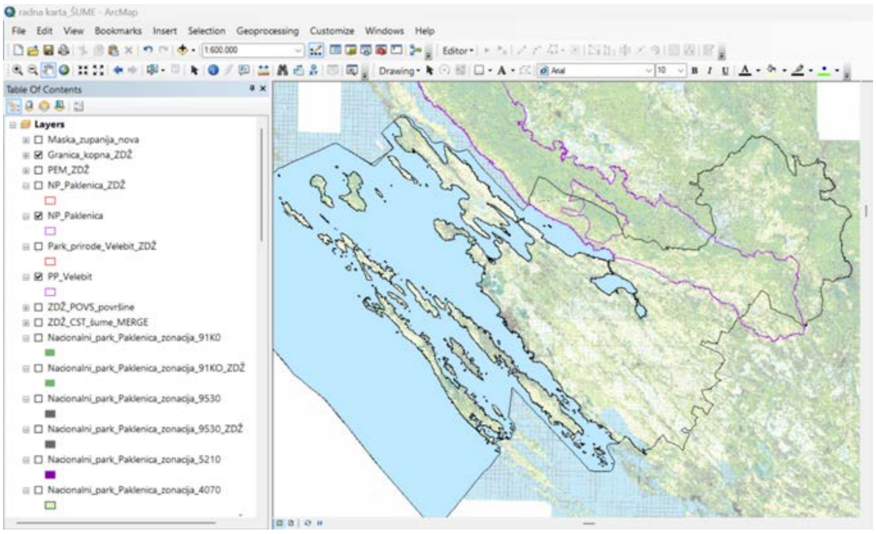
a) Geoprocessing Clip

Korišten za izdvajanje prostornih podataka unutar istraživanog područja, granica Zadarske županije:

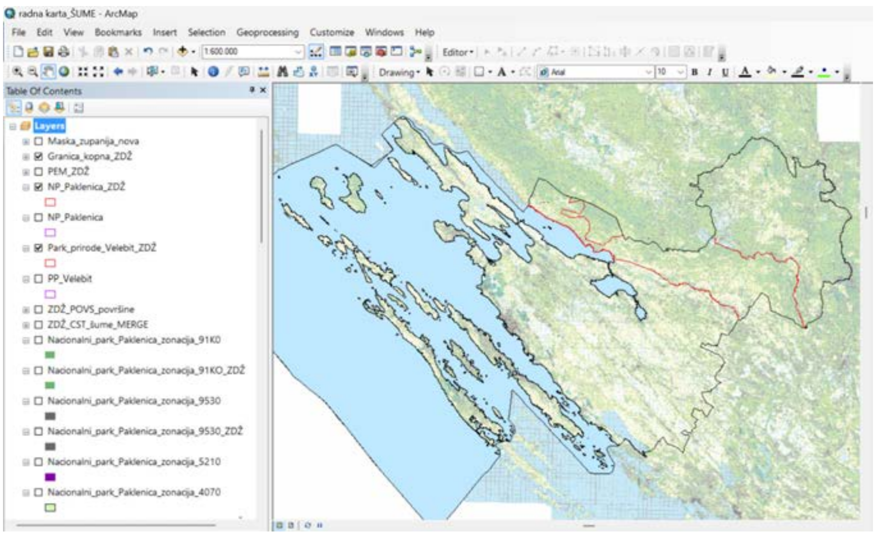
i) granice NP Paklenica
ii) granice PP Velebit
iii) šumski CST

Budući da se Natura 2000 područja Nacionalnog parka Paklenica (HR2000871) i Parka prirode Velebit (HR5000022) protežu izvan županije (Slika 1) stvoreni su novi .shp slojevi koji obuhvaćaju samo istraživano područje (Slika 2).

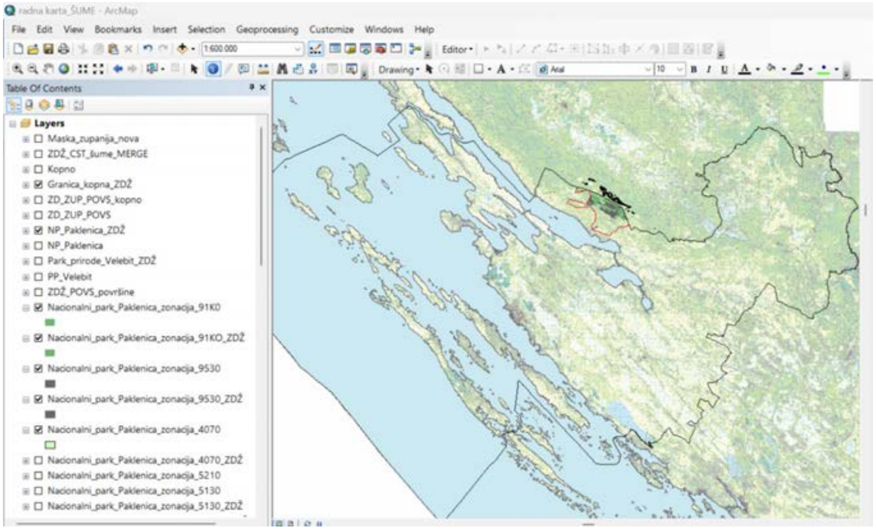
Od službenih podataka o rasprostranjenosti šumskih CST (Slika 3) izrađeni su zasebni .shp slojevi prikazujući njihovu prostornu pokrivenost unutar županije (Slika 4).



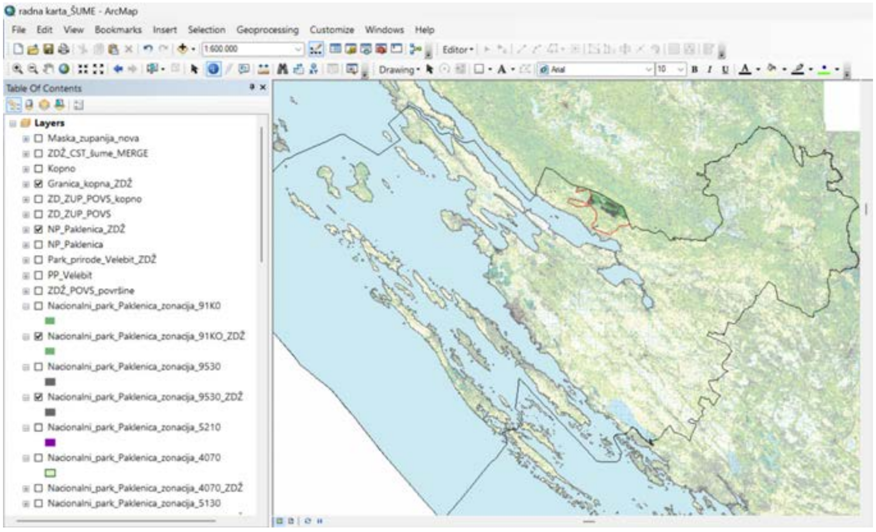
Slika 1. Granica Zadarske županije, Nacionalnog parka Paklenica (HR2000871) i Parka prirode Velebit (HR5000022).
Figure 1 Borders of Zadar County, Paklenica National Park (HR2000871) and Velebit Nature Park (HR5000022).



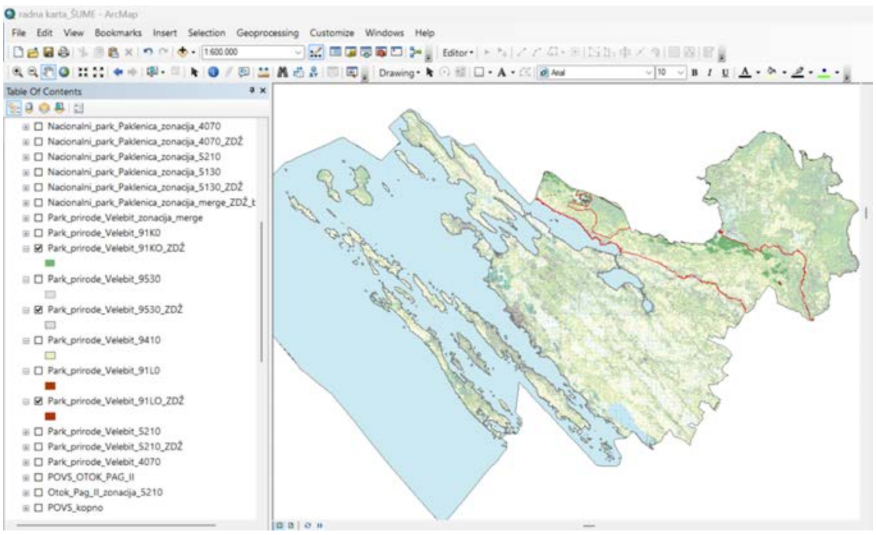
Slika 2. Granice Nacionalnog parka Paklenica (HR2000871) i Parka prirode Velebit (HR5000022) unutar Zadarske županije.
Figure 2 Borders of Zadar County, Paklenica National Park (HR2000871) and Velebit Nature Park (HR5000022) within Zadar County.



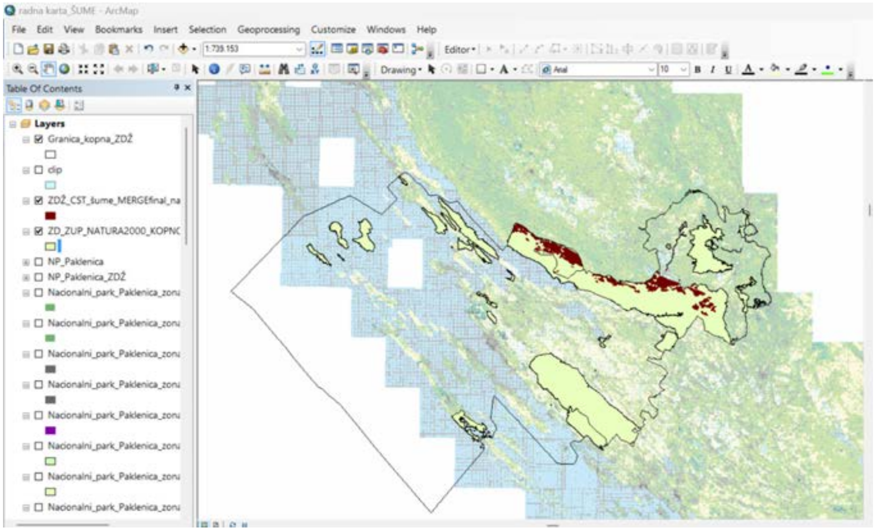
Slika 3. Prostorna pokrivenost šumskih CST u području HR2000871 NP Paklenica ekološke mreže Natura 2000.
Figure 3 Spatial coverage of forest target habitat types in the Natura 2000 site HR2000871 Paklenica National Park.



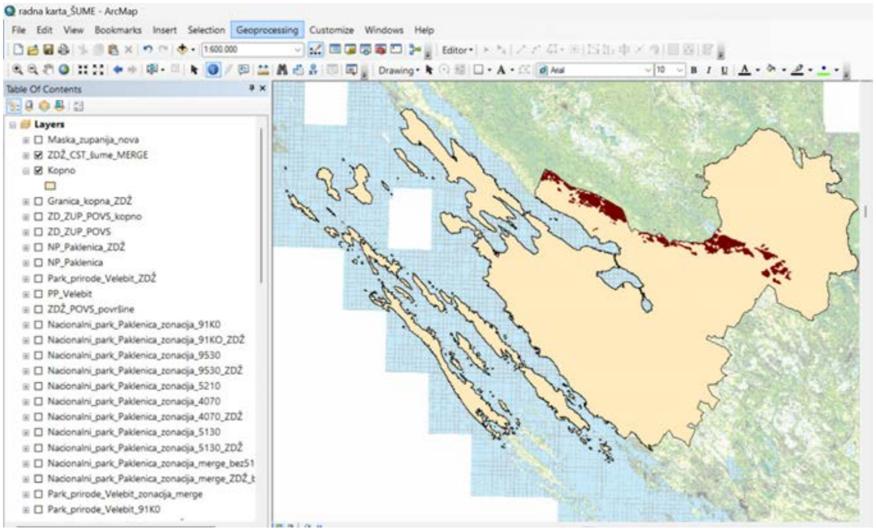
Slika 4. Prostorna pokrivenost šumskih CST u području HR2000871 NP Paklenica ekološke mreže Natura 2000 u Zadarskoj županiji.
Figure 4 Spatial coverage of forest target habitat types in the Natura 2000 site HR2000871 Paklenica National Park in Zadar County.



Slika 5. Prostorna pokrivenost šumskih CST u području HR5000022 Park prirode Velebit ekološke mreže Natura 2000 u Zadarskoj županiji.
Figure 5 Spatial coverage of forest habitats types in the Natura 2000 site HR5000022 Velebit Nature Park in Zadar County.



Slika 6. Prostorna pokrivenost šumskih CST u odnosu na kopneni dio POVS Natura 2000 područja Zadarske županije.
Figure 6 Spatial coverage of forest habitats types in relation to the land area of the species and habitat types of Natura 2000 sites of Zadar County.



Slika 7. Prostorna pokrivenost šumskih CST u ukupnoj kopnenoj površini Zadarske županije.
Figure 7 Spatial coverage of forest target habitat types in the Natura 2000 site HR2000871 Paklenica National Park.

b) Geoprocessing Merge

Korišten je za integraciju geometrijskih i atributivnih podataka iz više slojeva. Stvoreni su jedinstveni .shp slojevi potrebni za izračune ukupnih površina u hektarima (ha):

i) kopnena POVS područja (Slika 6),
ii) šumski CST unutar Zadarske županije (Slike 6 i 8),
iii) prostorna pokrivenost šumskih CST u području NP Paklenica (Slika 9),
iv) prostorna pokrivenost šumskih CST u području Parka prirode Velebit u Zadarskoj županiji (Slike 5 i 10).

c) Izračun površina

Površine CST analizirane su za 91 POVS područje unutar Zadarske županije. Analiza je utvrdila prisutnost šumskih CST samo u NP Paklenica i PP Velebit.

Na temelju atributnih podataka iz novog .shp sloja koji obuhvaća sve šumske CST unutar Zadarske županije, izračunati su udjeli šumskih CST u odnosu na kopneni dio POVS područja (Slika 6) i ukupnu kopnenu površinu županije (Slika 7).

d) Preklapanje slojeva i prostorni odnosi

WFS usluga omogućila je analizu vektorskih podataka,

Tablica 1. Šumski CST u Republici Hrvatskoj.
Table 1 Forest habitat types in the Republic of Croatia.

Šifra *Code*	**Naziv stanišnog tipa** *Name of the habitat type*	**Biogeografska regija** *Biogeographical region*		
		Kontinentalna *Continental*	**Alpska** *Alpine*	**Mediteranska** *Mediterranean*
9110	Bukove šume *Luzulo-Fagetum* *Luzulo-Fagetum beech forests*	x	x	
9130	Bukove šume *Asperulo-Fagetum* *Asperulo-Fagetum beech forests*	x	x	
9160	Subatlantske i srednjoeuropske hrastove i hrastovo-grabove šume *Carpinion betuli* *Sub-Atlantic and medio-European oak or oak-hornbeam forests of the Carpinion betuli*	x		x
9180*	Šume velikih nagiba i klanaca *Tilio-Acerion** *Tilio-Acerion forest of slopes, screes and ravines**	x	x	
91D0*	Cretne šume* *Bog woodland**	x	x	
910E0*	Aluvijalne šume (*Alno-Padion*, *Alnion incanae*, *Salicion albae*)* *Alluvial forests with Alnus glutinosa and Fraxinus excelsior (Alno-Padion, Alnion incanae, Salicion albae)**	x	x	
91F0	Poplavne miješane šume *Quercus robur*, *Ulmus laevis*, *Ulmus minor*, *Fraxinus excelsior* ili *Fraxinus angustifolia* *Riparian mixed forest of Quercus robur, Ulmus laevis and Ulmus minor, Fraxinus excelsior or Fraxinus angustifolia along the great rivers (Ulmenion minoris)*	x	x	x
91H0*	Panonske šume s *Quercus pubescens** *Pannonian woods with Quercus pubescens**	x		
91K0	Ilirske bukove šume (*Aremonio-Fagion*) *Illyrian Fagus sylvatica forests (Aremonio-Fagion)*	x	x	x
91L0	Ilirske hrastovo-grabove šume (*Erythronio-Carpinion*) *Illyrian oak-hornbeam forests (Erythronio-carpinion)*	x	x	
91M0	Panonsko-balkanske šume kitnjaka i sladuna *Pannonian-Balkanic Turkey oak-sessile oak forests*	x	x	
91R0	Dinarske borove šume na dolomitu (*Genisto januensis-Pinetum*) *Dinaric dolomite Scots pine forests (Genisto januensis-Pinetum)*		x	
9260	Šume pitomog kestena (*Castanea sativa*) *Castanea sativa woods*	x		x
9320	Šume divlje masline i rogača (*Olea* i *Ceratonion*) *Olea and Ceratonia forests*			x
9340	Vazdazelene šume česmine (*Quercus ilex*) *Quercus ilex and Quercus rotundifolia forests*			x
9410	Acidofilne šume smreke brdskog i planinskog pojasa (*Vaccinio-Piceetea*) *Acidophilous Picea forests of the montane to alpine levels (Vaccinio-Piceetea)*		x	
9530*	(Sub-) mediteranske šume endemičnog crnog bora* *(Sub-)Mediterranean pine forests with endemic black pines**		x	x
9540	Mediteranske šume endemičnih borova *Mediterranean pine forests with endemic Mesogean pines*			x

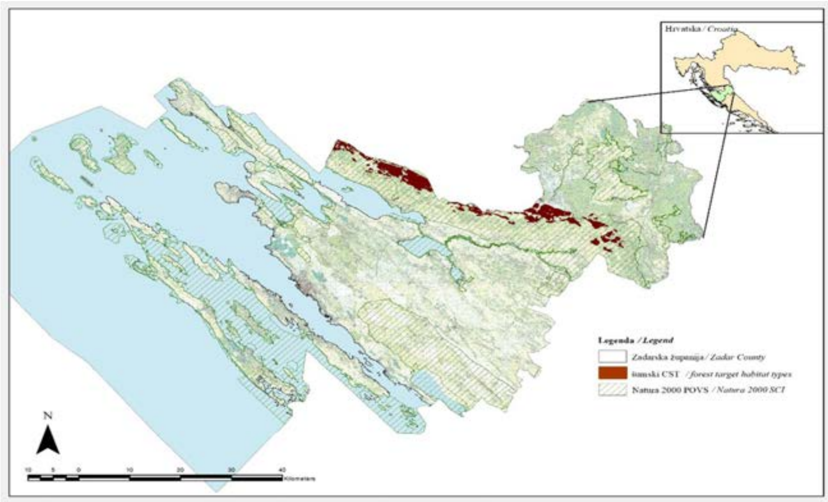
uključujući preklapanje slojeva i identifikaciju prostornih odnosa između šumskih CST i granica Natura 2000 područja unutar Zadarske županije, čime je potvrđena njihova rasprostranjenost.

Vizualizacija podataka - *Data visualization*

Za prikaz kartografskih podloga korištena je WMS usluga, uključujući granice administrativnih jedinica i topografske karte, čime je omogućena vizualizacija prostorne pokrivenosti šumskih CST (prikazano na Slikama 8, 9 i 10).

Tablica 2. Šumski CST područja ekološke mreže Natura 2000 zastupljeni na teritoriju Zadarske županije.
Table 2 Forest habitat types in Natura 2000 sites in the territory of Zadar County.

Šifra *Code*	Naziv stanišnog tipa *Name of the habitat type*	Površina Area (ha)
91K0	Ilirske bukove šume (*Aremonio-Fagion*) *Illyrian Fagus sylvatica forests (Aremonio-Fagion)*	5.789,55
9530*	(Sub-) mediteranske šume endemičnog crnog bora* *(Sub-)Mediterranean pine forests with endemic black pines**	1.039,68
91L0	Ilirske hrastovo-grabove šume (*Erythronio-Carpinion*) *Illyrian oak-hornbeam forests (Erythronio-Carpinion)*	20,33
	UKUPNO *TOTAL*	6.849,56



Slika 8. Prostorna pokrivenost šumskih CST u područjima ekološke mreže Natura 2000 na području Zadarske županije.
Figure 8 Spatial coverage of forest habitat types in Natura 2000 sites in the Zadar County.

REZULTATI I RASPRAVA
RESULTS AND DISCUSSION

Ciljni stanišni tipovi (CST) koji se odnose na šumska staništa zastupljeni na teritoriju Republike Hrvatske za koje su izdvojena područja ekološke mreže Natura 2000 prikazani su u Tablici 1 (Uredba o izmjenama Uredbe o ekološkoj mreži i nadležnostima javnih ustanova za upravljanje područjima ekološke mreže, NN 119/2023).

Od navedenih 18 CST u Tablici 1, na prostoru Zadarske županije rasprostranjeno ih je tri (Tablica 2) i to samo u dva područja ekološke mreže:

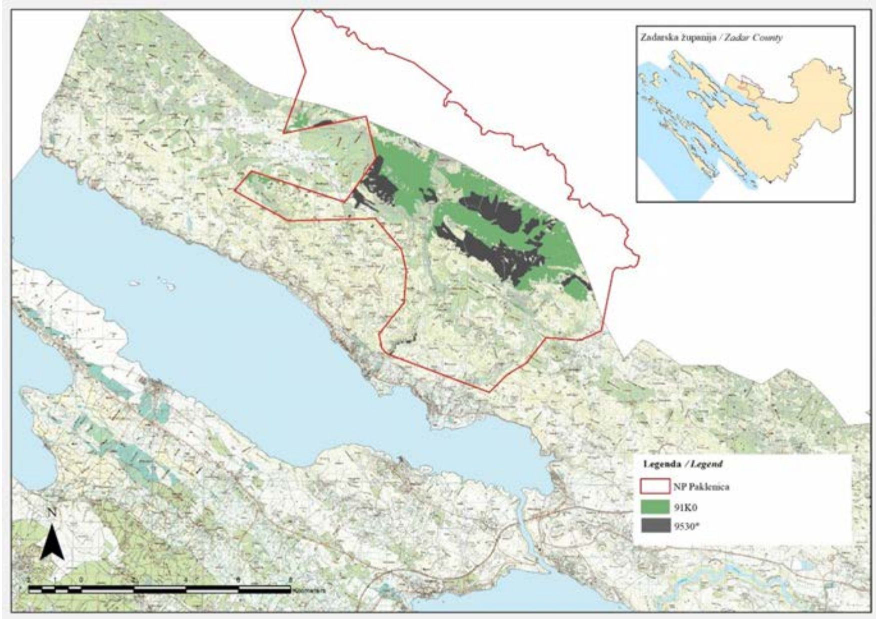
1. HR2000871 NP Paklenica
2. HR5000022 PP Velebit

Upotrebom GIS alata kreirani su novi slojevi šumskih CST za NP Paklenica, PP Velebit i ukupno za Zadarsku županiju, na temelju kojih su izračunate površine. Dobiven je rezultat da su u Zadarskoj županiji šumski CST rasprostranjeni na 6.849,56 ha, što čini svega 5,55 % kopnenog dijela Natura 2000 POVS područja Zadarske županije, odnosno 1,88 % kopnenog dijela županije. Prostorna pokrivenost šumskih CST na području Zadarske županije prikazana je na Slici 8.

Područje HR2000871 Nacionalni park Paklenica obuhvaća površinu od 9.507,56 ha od kojih se 6.447,72 ha nalazi na teritoriju Zadarske županije. Ukupna površina šumskih CST iznosi 3.160,98 ha, od kojih 2.032,81 ha otpada na područje Zadarske županije (Tablica 3, Slika 9).

Tablica 3. Šumski CST u području HR2000871 NP Paklenica.
Table 3 Forest habitat types in HR2000871 Paklenica National Park site .

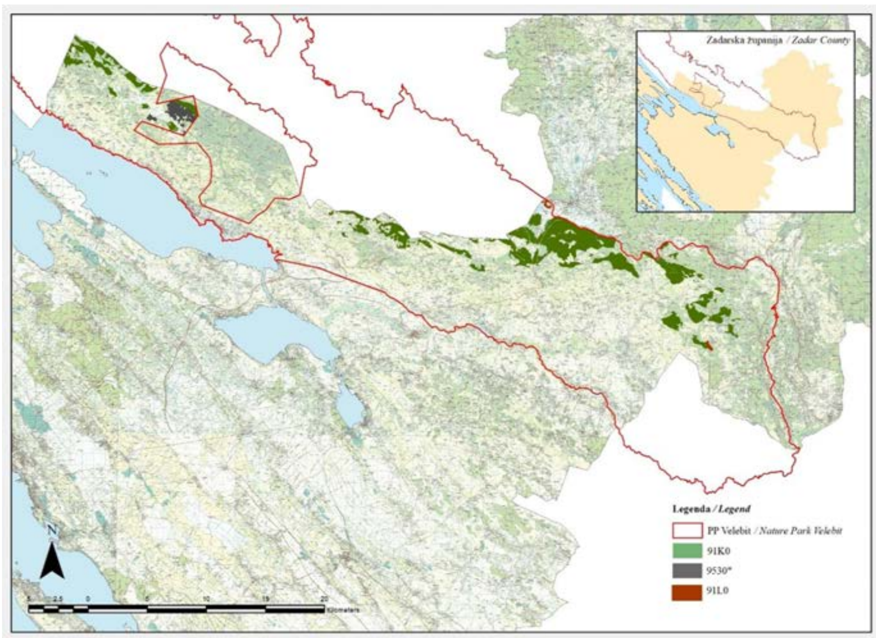
Šifra *Code*	Naziv stanišnog tipa *Name of the habitat type*	Površina (ha) *Area (ha)* u NP Paklenica *in NP Paklenica*	Površina (ha) *Area (ha)* u Zadarskoj županiji *in Zadar County*
91K0	Ilirske bukove šume (*Aremonio-Fagion*) *Illyrian Fagus sylvatica forests (Aremonio-Fagion)*	2.392,02	1.266,15
9530*	(Sub-) mediteranske šume endemičnog crnog bora* *(Sub-)Mediterranean pine forests with endemic black pines**	768,96	766,66
	UKUPNO *TOTAL*	3.160,98	2.032,81



Slika 9. Prostorna pokrivenost šumskih CST u području HR2000871 NP Paklenica u Zadarskoj županiji.
Figure 9 Spatial coverage of forest habitat types in HR2000871 Paklenica National Park site in Zadar County.

Tablica 4. Šumski CST u području HR5000022 Park prirode Velebit.
Table 4 Forest habitat types in HR5000022 Velebit Nature Park site.

Šifra *Code*	**Naziv stanišnog tipa** *Name of the habitat type*	**Površina (ha)** *Area (ha)*	
		u PP Velebit *in NP Velebit*	**u Zadarskoj županiji** *in Zadar County*
91K0	Ilirske bukove šume (*Aremonio-Fagion*) *Illyrian Fagus sylvatica forests (Aremonio-Fagion)*	65.902,93	4.523,40
9530*	(Sub-) mediteranske šume endemičnog crnog bora* *(Sub-)Mediterranean pine forests with endemic black pines**	561,20	273,02
91L0	Ilirske hrastovo-grabove šume (*Erythronio-Carpinion*) *Illyrian oak-hornbeam forests (Erythronio-Carpinion)*	566,73	20,33
9410	Acidofilne šume smreke brdskog i planinskog pojasa (*Vaccinio-Piceetea*) *Acidophilous Picea forests of the montane to alpine levels (Vaccinio-Piceetea)*	4.039,36	0
	UKUPNO *TOTAL*	71.070,22	4.816,75



Slika 10. Prostorna pokrivenost šumskih CST u području HR5000022 Park prirode Velebit u Zadarskoj županiji.
Figure 10 Spatial coverage of forest habitats types in HR5000022 Velebit Nature Park site in Zadar County.

Područje HR5000022 Park prirode Velebit obuhvaća površinu od 182.852,31 ha (stvarna površina Parka prirode Velebit, bez površina nacionalnih parkova Sjeverni Velebit i Paklenica) od kojih se 50.661,01 ha nalazi na teritoriju Zadarske županije. Ukupna površina šumskih CST je 71.070,22 ha, od kojih se 4.816,75 ha nalazi na područje Zadarske županije (Tablica 4, Slika 10). Ukupnom površinom CST na ovome području obuhvaćene su i 9410 Acidofilne šume smreke brdskog i planinskog pojasa (*Vaccinio-Piceetea*), međutim nalaze se izvan područja Zadarske županije (Tablica 4).

Kako je prethodno i navedeno, ekološka mreža Natura 2000 uključuje 36,67 % kopnene površine (MINGOR 2019) Republike Hrvatske. U Zadarskoj županiji ukupna površina POVS područja ekološke mreže Natura 2000 iznosi 189.176,30 ha od kojih se 123.188,52 ha odnosi na kopneni dio županije, odnosno 33,85 %. U Zadarskoj županiji šumski CST rasprostranjeni su na 6.849,56 ha, što čini svega 5,55 % kopnenog dijela POVS područja, odnosno 1,88 % kopnenog dijela županije. Dobiveni rezultat možemo usporediti s rezultatima koje navodi Europska agencija za okoliš prema kojima se u Europi nalazi oko 5 % netaknutih šuma (Europska agencija za okoliš 2010). Također, postotak šumskih CST pod Naturom 2000 u Zadarskoj županiji usporediv je s već spomenutom procjenom za Ujedinjenu Kraljevinu i Irsku gdje šumska staništa zauzimaju najniže postotne vrijednosti površine, tek do 10 % Nature 2000, a u suprotnosti s Bugarskom i Slovačkom koje imaju najviše postotne vrijednosti površine, preko 50 % Nature 2000 (Europski revizorski sud 2013). Ukoliko dobivene postotke usporedimo po istom izvoru s državama članicama EU mediteranskog područja, šume zauzimaju 44 % kopnene površine Nature 2000 u Francuskoj, a isti postotak ima i Hrvatska. U Italiji šume zauzimaju 51 %, a u Grčkoj 43 % kopnene površine Nature 2000. Rezultati ovoga istraživanja pokazuju da šumski CST u Zadarskoj županiji, izdvojeni od ostatka Hrvatske, zauzimaju znatno manji udio kopnene površine Nature 2000, iako šume i šumsko zemljište čine više od polovice ukupne površine županije (Plan razvoja Zadarske županije 2021. – 2027. (Plan razvoja 2021–2027)). Barbati i dr. (2014) navode kako su u različitim regijama Europe razvedeni posebni tipovi šuma koji su prilagođeni lokalnim uvjetima okoliša. Srednjom Europom obično dominiraju bukove šume, dok su crnogorične šume najčešće u planinskim područjima i na sjeveru Europe. U mediteranskoj regiji prevladavaju mješovite šume hrasta i crnogorice. Šumski CST Zadarske županije sasvim odgovaraju njihovom navodu. Isti autori također procjenjuju da ukupno postoji 14 kategorija i 79 tipova šumskih staništa u EU-u dok je u Prilogu I. Direktive o staništima navedeno ukupno 85 šumskih stanišnih tipova, uključujući 29 prioritetnih staništa (Barbati i dr. 2014). U RH postoji 18 šumskih CST te od toga 5 prioritetnih stanišnih tipova. U Zadarskoj županiji nalazimo svega 3 šumska CST, od kojih jedan prioritetni stanišni tip. Treba imati na umu da postoji određena razlika u podacima površina šumskih staništa, šumskih staništa pod Natura 2000 i šumskih CST.

U području HR2000871 NP Paklenica ciljni stanišni tip ilirske bukove šume (*Aremonio-Fagion*) (91K0) zabilježen je na područjima Suva Draga Klimenta i Oglavinovac-Javornik gdje se nalaze najstarije bukove šume kojima nije gospodareno barem 80 godina, a prosječna starost bukovih stabala procijenjena je na 200 – 250 godina (UNESCO 2017). Stoga ove šume imaju prašumski karakter i iznimnu ekološku vrijednost, koja se osobito očituje u velikom bogatstvu gljiva vezanih uz drvne ostatke bukve, a među kojima je pronađen znatan broj vrsta prethodno nezabilježenih u Hrvatskoj, ali i nekolicina vrsta novih za znanost. Dvije rijetke i ugrožene vrste gljiva, uvrštene u Crvenu knjigu gljiva Hrvatske u kategoriji ugroženosti osjetljiva (VU) (Tkalčec i dr. 2008), koje su ujedno i indikatori prašumskih staništa, su prašumska planinka (*Tatraea dumbirensis* (Velen.) Svrček) te krhka iglokoška (*Dentipellis fragilis* (Pers.) Donk), kojoj je ovo jedino poznato nalazište na Velebitu (dok su svi ostali hrvatski nalazi na području Plitvičkih jezera). Ciljni stanišni tip (sub-) mediteranske šume endemičnog crnog bora (9530*), koji je istovremeno i prioritetni stanišni tip, obuhvaća šume mediteransko-montanog pojasa na dolomitnoj podlozi (visoka tolerancija na magnezij) u kojima prevladava crni bor (*Pinus nigra* J.F.Arnold subsp. *nigra*) ili endemični dalmatinski bor (*Pinus nigra* subsp. *dalmatica* (Vis.) Franco) (Topić i Vukelić 2009). Ove reliktne šume razvijene su tek na pojedinim lokacijama, a često su podložne požarima i zarastanju listopadnim vrstama u sklopu prirodnog procesa sukcesije tipova vegetacije. Ta zajednica je pionirskog karaktera, odnosno zauzima ogoljele i/ili opožarene površine rastući na plitkim skeletnim tlima istaknutih grebena i glavica. U Planu upravljanja Nacionalnim parkom Paklenica i Natura 2000 područjem HR2000871 (PU 6032 2023) kao šumska staništa navedena su i: 4070* Klekovina bora krivulja (*Pinus mugo* Turra) s dlakavim pjenišnikom (*Rhododendron hirsutum* L.); 5210 Mediteranske makije u kojima dominiraju borovice *Juniperus* spp.; te 5130 Sastojine *Juniperus communis* L. na kiseloj ili bazičnoj podlozi, iako normativno nisu definirana kao šumska u ekološkoj mreži Natura 2000 (Uredba o izmjenama Uredbe o ekološkoj mreži i nadležnostima javnih ustanova za upravljanje područjima ekološke mreže, NN 119/2023). CST 5130 (Sastojine *Juniperus communis* na kiseloj ili bazičnoj podlozi) nisu istražene ni kartirane na ovome području te bi ih tek trebalo kartirati. Opće stanje šuma i šumskih ekosustava na području

Nacionalnog parka Paklenica i područja HR2000871 je dobro, a u velikim dijelovima i izvrsno. Šume se razvijaju neometano te se u njima odvijaju prirodni procesi starenja i obnove šume. Iznimna kvaliteta staništa bukovih šuma na području nacionalnog parka kao posljedica dugogodišnje zaštite područja razlog je upisa bukovih šuma na UNESCO-ov Popis svjetske baštine. Rizik od požara na ovim šumskim staništima relativno je visok, no redovito se poduzimaju preventivne mjere zaštite od požara, čime se nastoji što više smanjiti rizik od pojave požara (PU 6032 2023).

U području HR5000022 PP Velebit ciljni stanišni tip ilirske bukove šume (*Aremonio-Fagion*) (91K0) rasprostranjen je duž cijelog Velebita. Šume su izuzetno raznolike te obuhvaćaju više različitih šumskih zajednica (PU 6017 2022). Posebno se ističu šume mediteransko-montanog (brdskog) pojasa na dolomitnoj podlozi u kojima prevladava crni bor, a koje čine prioritetni ciljni stanišni tip (sub-) mediteranske šume endemičnog crnog bora (9530*)). Kao što je navedeno za isti CST na području NP Paklenica, vrste specifične za ovo prioritetno stanište su crni bor (*P. nigra* subsp. *nigra*) te dalmatinski crni bor (*P. nigra* subsp. *dalmatica*) (Topić i Vukelić 2009). Često su podložne požarima i sukcesiji – zarastanju listopadnim vrstama u sklopu prirodnih procesa. Reliktne šume crnog bora s pustenastom dunjaricom (*Cotoneastro-Pinetum nigrae*) razvijene su tek na pojedinim lokacijama. Obično se razvijaju na dolomitu, a manjim dijelom na vapnencu. Posebno se ističu na području Senjske Drage, a u Zadarskoj županiji nalazimo ih na Stražbenici, povrh Velikog Rujna te na Goliću (Vukelić i dr. 2003). Najznačajnije sastojine hrastovo-grabovih šuma (šume hrasta kitnjaka (*Quercus petraea* (Matt.) Liebl.) i običnog graba (*Carpinus betulus* L.)) predstavljaju ciljni stanišni tip ilirske hrastovo-grabove šume (*Erythronio-Carpinion*) (91L0), a unutar Parka prirode Velebit ih nalazimo na četiri velika kompleksa: jugoistočno od Medka, oko Malovana, na području iznad Kosinjskog Bakovca (Pršić – Crni vrh) te u Zadarskoj županiji južno od Svetog Roka. Rastu na visini od 450 do 800 metara (Vukelić i dr. 2003). Šume na području Parka prirode Velebit i u području HR5000022 uglavnom su prirodnog podrijetla, nastale prirodnim pomlađivanjem od starih sastojina, velike biološke i gospodarske vrijednosti, bez alohtonih vrsta i vrlo dobrog općeg stanja. Značajnu potencijalnu ugrozu za očuvanje šumskih ekosustava općenito predstavljaju klimatske promjene, čiji su utjecaji mjestimično već vidljivi u Parku prirode Velebit. Kao posljedica naglih i ekstremnih vremenskih pojava dolazi do vjetroizvala i lavina, učestalije vidljivih na području južnog Velebita i Zadarske županije. Nepovoljni klimatski uvjeti i sušenje šume pogoduju razvoju potkornjaka, koji u pojedinim godinama imaju izraženo povećanje brojnosti, što može izazvati odumiranje većeg broja stabala. Šume s prirodnom strukturom i sastavom otpornije su u usporedbi s umjetno podignutim kulturama. Na području Parka prirode Velebit nije uspostavljeno sustavno praćenje stanja šumskih ciljnih stanišnih tipova (PU 6017 2022).

Rezultati ovoga istraživanja mogu se koristiti kao polazište za daljnje studije i planiranje očuvanja prirodnih staništa unutar ekološke mreže Natura 2000 u Zadarskoj županiji. Glavni izazovi koje su prijavile zemlje uključene u praćenje i izvještavanje o stanju očuvanosti tipova šumskih staništa bili su povezani s njihovom identifikacijom i kartiranjem, dizajnom i troškovima praćenja (posebno za rijetke tipove šumskih staništa), identifikacijom učinkovitih pokazatelja, definiranjem referentnog stanja, agregacijom vrijednosti pokazatelja u globalno stanje očuvanosti i ažuriranjem stanja očuvanosti staništa (Alberdi i dr. 2019).

ZAKLJUČCI

CONCLUSIONS

Na području Zadarske županije unutar ekološke mreže Natura 2000 nalaze se tri šumska CST: ilirske bukove šume (*Aremonio-Fagion*), (sub-) mediteranske šume endemičnog crnog bora i ilirske hrastovo-grabove šume (*Erythronio-Carpinion*). Nalaze se u dva područja ekološke mreže: HR2000871 Nacionalni park Paklenica i HR5000022 Park prirode Velebit. Šumski CST prostiru se na površini od 6.849,56 ha, što čini svega 5,55 % kopnenog dijela Natura 2000 područja očuvanja značajnih za vrste i stanišne tipove (POVS) Zadarske županije, odnosno 1,88 % kopnenog dijela županije. U Zadarskoj županiji, u kojoj ekološka mreža Natura 2000 pokriva 5.789,55 ha, najzastupljeniji je šumski stanišni tip ilirske bukove šume (*Aremonio-Fagion*), a slijede ga (sub-) mediteranske šume endemičnog crnog bora s 1.039,68 ha, dok najmanju površinu od svega 20,33 ha zauzimaju ilirske hrastovo-grabove šume (*Erythronio-Carpinion*). CST (sub-) mediteranske šume endemičnog crnog bora ujedno je i prioritetni stanišni tip.

Ilirske bukove šume (*Aremonio-Fagion*) na području Zadarske županije nalazimo u sve tri biogeografske regije: kontinentalnoj, alpskoj i mediteranskoj. (Sub-) mediteranske šume endemičnog crnog bora na području Zadarske županije nalazimo u dvije biogeografske regije, alpskoj i mediteranskoj, dok ilirske hrastovo-grabove šume (*Erythronio-Carpinion*) nalazimo samo u jednoj biogeografskoj regiji, i to u alpskoj.

Istraživanje je također pokazalo razliku između znanstveno-stručnog i normativnog određenja za CST. Postavlja se pitanje prepoznaju li šumarska znanost i struka određena staništa kao šumske stanišne tipove, kao na primjer u slučaju sljedećih CST: 4070* Klekovina bora krivulja (*Pinus mugo*) s dlakavim pjenišnikom

(*Rhododendron hirsutum*), 5210 Mediteranske makije u kojima dominiraju borovice (*Juniperus* spp.) te 5130 Sastojine *Juniperus communis* na kiseloj ili bazičnoj podlozi.

Opće stanje šuma i šumskih ekosustava na području Nacionalnog parka Paklenica i u području HR2000871 ekološke mreže Natura 2000 je dobro, a u velikim dijelovima i izvrsno. Rizik od požara u šumskim staništima je relativno visok te je nužno poduzimati preventivne mjere zaštite od požara s ciljem smanjivanja rizika od pojave požara.

Šume i šumski ekosustavi na području Parka prirode Velebit i područja HR5000022 uglavnom su prirodnog podrijetla. Nastali su prirodnim pomlađivanjem starih sastojina, imaju veliku biološku i gospodarsku vrijednost, ne sadrže alohtone vrste te su vrlo dobrog općeg stanja. Međutim, klimatske promjene predstavljaju značajnu potencijalnu ugrozu za očuvanje šumskih ekosustava.

Iz tih je razloga nužno što prije uspostaviti sustavno praćenje stanja šumskih ciljnih stanišnih tipova.

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SUMMARY

In three biogeographic regions in Zadar County, there are three forest target habitat types, one of which is identified as a priority habitat type. Spatial analyses are essential for effective planning and management of Natura 2000 sites, which is why they were chosen as the aim of this research. Geoprocessing methods in ArcGIS were used to create new values, with the goal of calculating the areas of forest target habitat types in the Natura 2000 sites in Zadar County. By using GIS (Geographic Information System) tools, the result obtained was that forest habitat types in Zadar County cover 6,849.56 ha, accounting for 5.55% of the land area of the Natura 2000 sites important for species and habitat types, or 1.88% of the land area of the county. The general condition of the forest target habitat types in Zadar County ranges from good, very good to excellent. However, there is a high risk of forest fires, and climate change poses a significant threat. It is necessary to establish a monitoring system of the forest target habitat types' condition. The results of this research may be used as a basis for further studies and planning of the conservation of natural habitats within the Natura 2000 sites in Zadar County.

KEY WORDS: Natura 2000 ecological network, spatial analyses, forest habitat types, Zadar County

IZNIMNA STABLA NAŠIH ŠUMA

Najveći hrast lužnjak (*Quercus robur* L.) u Hrvatskoj raste u prašumi Prašnik

Igor Anić, Vinko Paulić, Domagoj Trlin[1]

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

Stablo koje svakako zaslužuje otvoriti novu rubriku Šumarskog lista je naš najveći hrast lužnjak koji raste u prašumi Prašnik.

Prašuma Prašnik je posljednji ostatak starih šuma hrasta lužnjaka kakve su u Slavoniji rasle prije prve polovice 20. stoljeća. Nalazi se u neposrednoj blizini naselja Novi Varoš u općini Stara Gradiška. Izlučena je iz redovitog gospodarenja 5. rujna 1929., u razdoblju kada su oplodnom sječom pomlađeni posljednji stari slavonski hrastici. Sastojina je 3. lipnja 1965. dobila status posebnog rezervata šumske vegetacije. Nalazi se na 96 m nadmorske visine i ima površinu od 54,46 ha. U Prašniku su zastupljene dvije šumske zajednice: tipična šuma hrasta lužnjaka i običnog graba (*Carpino betuli-Quercetum roboris typicum* Rauš 1973) i šuma hrasta lužnjaka s velikom žutilovkom i rastavljenim šašem (*Genisto elatae-Quercetum roboris caricetosum remotae* Horvat 1938).

Najveće stablo hrasta lužnjaka u Hrvatskoj raste u sjevernom dijelu sastojine, u šumskoj zajednici hrasta lužnjaka i običnog graba. Prvu detaljnu izmjeru stabla obavili su 22. rujna 2025. godine prof. dr. sc. Igor Anić, izv. prof. dr. sc. Vinko Paulić i dr. sc. Domagoj Trlin sa Zavoda za ekologiju i uzgajanje šuma Fakulteta šumarstva i drvne tehnologije Sveučilišta u Zagrebu.

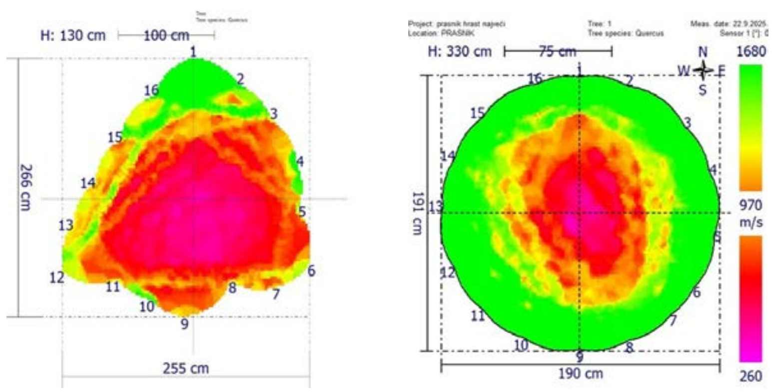
Mjerenje visina obavljeno je visinomjerom Vertex. Prsni promjer stabla nije moguće precizno izmjeriti promjerkom, pa je pomoću mjerne vrpce izmjeren opseg. Nedohvatni promjer izmjeren je Bitterlichovim zrcalnim relaskopom s CP skalom. Izmjera unutrašnjeg stanja stabla obavljena je zvučnim tomografom Rinntech Arbotom na visinama 1,3 i 3,3 m. Starost stabla procijenjena je nakon uzorkovanja Presslerovim svrdlom na visini 200 cm gdje su na izvrtku izmjerena 174 goda. Zbog truleži u središnjem dijelu debla ostatak do utvrđene starosti dodan je uzevši u obzir preostalu udaljenost do centra stabla i sposobnost stabla da u mladosti stvara šire godove (juvenilni rast).

Žilište stabla u odnosu na trasirku širine 1 m postavljenu u prsnoj visini.

PODACI IZMJERE

- visina stabla 42,4 m
- visina do prve zelene grane koja se može smatrati dijelom krošnje: 18,7 m
- visina do prve odlomljene krupne grane 10,3 m
- visina rašlje 13,2 m
- opseg stabla u prsnoj visini 819 cm (prsni promjer 261 cm)
- opseg stabla na visini 200 cm na kojoj je uzet izvrtak za dendrokronološku analizu iznosi 688 cm (promjer 219 cm)
- opseg stabla na visini 338 cm na kojoj počinje deblo iznosi 600 cm (promjer 191 cm)
- promjer stabla na visini 10 m gdje završava čisto deblo iznosi 185 cm
- duljina čistog debla 6,62 m
- pravnost debla potpuna
- pad promjera čistog debla 0,9 cm/m
- volumen drva izračunat pomoću lokalne tarife 72 m^3
- opseg žilišta izmjeren kao kružnica oko vanjskog oboda 15,7 m
- žilište tvori 11 žila od kojih se najveća proteže do 330 cm visine
- dužina najveće žile 160 cm
- promjer krošnje u smjeru sjever – jug 28,7 m
- promjer krošnje u smjeru istok – zapad 28,9 m
- starost stabla približno 230 godina
- debljinski prirast stabla unazad 174 godine u rasponu 2,80 – 14,00 mm godišnje
- prosječni debljinski prirast unazad 174 godine iznosi 6,4 mm

[1] Akademik Igor Anić, izv. prof. dr. sc. Vinko Paulić, dr. sc. Domagoj Trlin, Sveučilište u Zagrebu Fakultet šumarstva i drvne tehnologije



Tomogram na prsnoj visini pokazuje u svom središnjem dijelu napredovalu trulež drva koja je dovela do stvaranja veće šupljine u unutrašnjosti tog dijela stabla dok se preostalo zdravo drvo nalazi na rubnim dijelovima pri čemu se posebno ističe sjeverni dio žilišta kod kojega je utvrđen najveći dio zdravog drva koje osigurava stabilnost stabla. Tomogram na visini 3,3 m također pokazuje centralno smješteno područje na kojemu zvučni valovi prolaze sporije u odnosu na rubne dijelove, ali veličina tog područja je takva da zdravi dijelovi drva čine više od polovice unutrašnjeg presjeka.

Dodatno, utvrđen je broj ponika na četiri plohe koje su postavljene na polovicama polumjera krošnje prema četiri strane svijeta u prosjeku je 33 kom./m^2, zabilježeni su izlazni otvori hrastove strizibube.

Zaključno, hrast lužnjak (*Quercur robur* L.) u prašumi Prašnik vjerojatno je najveće stablo te vrste drveća u Hrvatskoj s obzirom na opseg/promjer u prsnoj visini, visinu i volumen drva. Usporedivši ga s istovrsnim stablima na internetskoj stranici Monumental trees (www.monumentaltrees.com) može se zaključiti kako je njegova posebnost rast u sastojinskom sklopu, što pridonosi jedinstvenom pravilnom habitusu, velikoj duljini debla, malom padu promjera, velikoj visini i iznimno velikom volumenu drva.

Stablo ima dovoljne zalihe zdravog drva koje sprječavaju lom debla i brži razvoj truleži drva. Usporedbom rezultata izmjere zvučnim tomografom na dvije visine mjerenja vidljivo je povoljnije stanje unutrašnjeg stanja stabla s porastom visine. Oštećenja od hrastove strizibube koja su zabilježena pri vizualnom pregledu nižih dijelova stabla slažu se sa snimkama unutrašnjeg stanja drva. Usmjerenim debljinskim prirastom na žilištu stablo nastoji nadoknaditi nepovoljno unutrašnje stanje i osigurati mehaničku stabilnost.

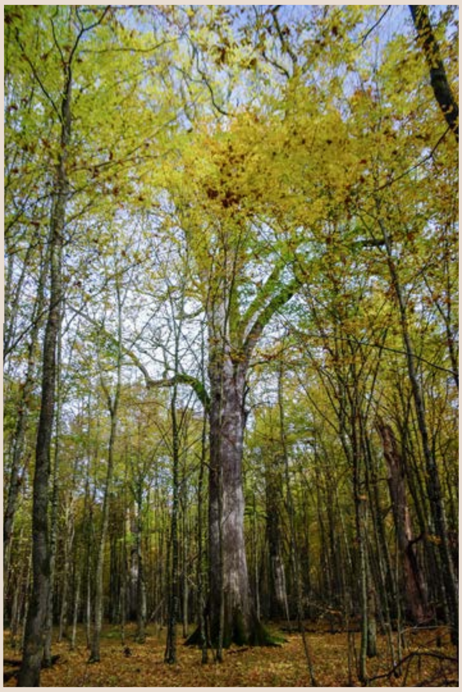
Jedinstveni habitus stabla rezultat je rasta u sastojinskom sklopu, zbog čega naš hrast lužnjak ima veliku visinu, potpuno pravno i čisto deblo te veliku drvnu zalihu. Potpuno odgovara Kozarčevom opisu u Slavonskoj šumi: *„Tu se dižu velebni hrastovi sa sivkastom korom, izrovanom ravnim brazdama, koje teku duž cijelog 20 metara visokog debla sa snažnom širokom krošnjom, kojano ga je okrunila, kao stasitog junaka kučma*."

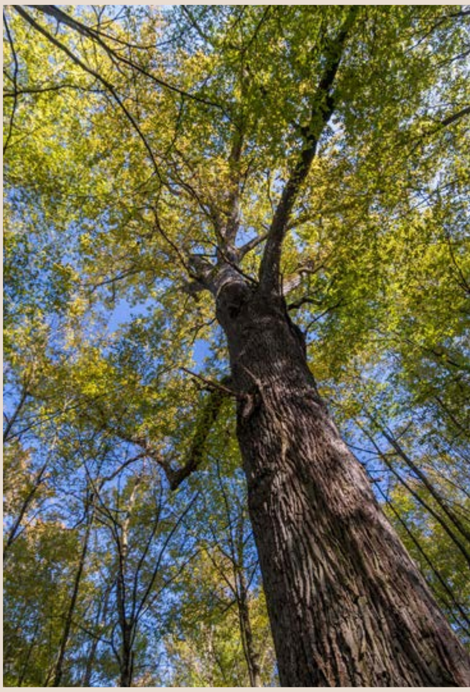
Autori prikaza. U prednjem planu brojan ponik nastao nakon dobrog uroda žira u jesen 2024. godine.

Tlo oko stabla zbijeno je zbog brojnih posjetitelja. To ne samo da šteti korijenskom sustavu, rastu stabla i prirodnom pomlatku nego je nespojivo s definicijom prašume. Ako se posjetitelji ne mogu izbjeći, preporuča se oko stabla na udaljenosti od 10 m podići ogradu kako bi se umanjilo gaženje tla. Monumentalnost stabla s te udaljenosti je izraženija. Na ogradu se može postaviti informativna tabla s osnovnim dendrometrijskim podacima i navod o štetnosti gaženja tla u njegovoj neposrednoj blizini.

OKOM ŠUMARA

Goran Dorić, revirnik u Šumariji Stara Gradiška fotografirao je prašumu Prašnik i čuveni hrast stotine puta; ovo je samo mali izbor





Hrvatsko šumarsko društvo ili Šumarsko društvo Hrvatske

Branko Meštrić[1]

Treba li se naše društvo zvati Hrvatsko šumarsko društvo ili Šumarsko društvo Hrvatske, bila je velika dilema hrvatskih šumara te davne 1945. godine. Prije 80 godina, u kolovozu 1945. okupili su se vrli šumari, prvi puta nakon rata na 66. redovitu godišnju skupštinu u svoj društveni dom u Vukotinovićevoj 2. Povjerenik HŠD-a ing. Ivo Čeović, na temelju dozvole Otsjeka narodne sigurnosti broj 7622/45. od 26. srpnja 1945. i formalno je sazvao skupštinu društva za dan 19. kolovoza 1945. Spomenutoga dana u zakazano vrijeme, u 9 sati ujutro, sakupila su se u dvorani Hrvatskoga šumarskog društva 82 redovita člana društva, predstavnici Ministarstva poljoprivrede i šumarstva, Gradskog N. O. i štampe. Skupština se primila svog posla i odrađivala točke dnevnog reda, sve dok na red nije došla 4. točka dnevnog reda - Promjena pravila.

Ing. Ivica Bastijančić bi zamoljen da čita član po član novih pravila i uspijeva doći do stavke prve u čl. 1. Ne znamo što je u prijedlogu točno pisalo, ali prof. Petračić istoga časa prekida čitanje i predlaže da ostane naziv društva Hrvatsko šumarsko društvo, a ne Šumarsko društvo Hrvatske (kao što je vjerojatno pisalo). Povjerenik ing. Ivo Čeović odmah daje na glasanje stavak 1. člana 1. Na sveopće zaprepaštenje od 82 prisutna člana za prihvat spornog člana, tj. za Šumarsko društvo Hrvatske glasalo je samo njih 26. I tu nastade rasprava. Ing. Z. Špoljarić u ime inicijativnog odbora obrazlaže da se išlo za tim da se iz društva ukloni svaki trag nacionalnom šovinizmu (?!).

Prof. dr. A. Petračić naglašava da je ime Hrvatsko šumarsko društvo nasljeđeno još 1917. od Hrvatsko-slavonskog šumarskog društva i da ne vidi razloga zašto bi ga danas trebalo mijenjati. Podržava ga i prof. dr. Đ. Nenadić.

Ing. A. Sedmak (koji je, usput rečeno stradao 12 dana kasnije „od zločinačke ruke" u Gorskom kotaru) pak staje na stranu inicijativnog odbora i pojašnjava predgovornicima da se stari naziv HŠD zasniva na pretpostavci o starim vremenima i političkim prilikama, a ta su vremena prošla. Ing. Z. Špoljarić ponovno izjavljuje da inicijativni odbor nije imao namjeru povrijediti tradiciju, već je nastojao da se ukloni svaka sumnja u nacionalni šovinizam i da se omogući sakupljanje svih šumara Hrvata i Srba u tome društvu. Priskače i ing. B. Čop koji drži da je inicijativa posve u skladu s novim političkim duhom koji danas vlada u Federativnoj Demokratskoj Jugoslaviji.

Kad prof. dr. A. Petračić napomene da je diskusija po tom pitanju izlišna, jer se skupština svojim glasanjem već izjasnila, izvjesni I. Kelez predlaže da se skupština, ni manje ni više, odmah raspusti. Toliko o glasanju i demokraciji.

I tko zna kako bi situacija završila, da pomirljivi ing. Čeović, predsjedavajući, nije predložio ponovno glasanje, ovaj puta tajno, što je skupština i prihvatila. Na kraju balade, a po obavljenom glasanju, ing. A. Premužić u ime skrutatora izjavljuje da je za naziv Šumarsko društvo Hrvatske glasalo njih 35, a za naziv Hrvatsko šumarsko društvo glasalo je njih 47. Ovim je glasanjem skupština prihvatila prijedlog prof. dr. A. Petračića da naziv društva ostane Hrvatsko šumarsko društvo.

Eto tako se prije 80 godina vodila „teška borba" samo za ime Hrvatsko šumarsko društvo.


SMRT FAŠIZMU — SLOBODA NARODU!
VJESNIK
JEDINSTVENE NARODNO OSLOBODILAČKE FRONTE HRVATSKE
Broj 104. | Zagreb, ponedjeljak 20. kolovoza 1945. | God. V.


Izabrana je nova uprava Hrvatskog šumarskog društva

ZAGREB, 19. kolovoza. — Na glavnoj skupštini Hrvatskog šumarskog društva, održanoj jutros u 9 sati na poljodjelsko-šumarskom fakultetu, Vukotinovićeva ul. 2., izabran je za predsjednika dr. Gjuro Nenadić, sveučilišni profesor, za potpredsjednika ing. Alfonz Hauders, za tajnika ing. Zrinko Grahovac i za blagajnika ing. Zvonko Špoljarić. Takodjer je izabrano 12 odbornika i 6 zamjenika.

Na skupštini je zaključeno, da se društvo i dalje ima zvati Hrvatsko šumarsko društvo. Raspravljani su prijedlozi u vezi s promjenom pravila. Društvo koje danas broji 82 člana osnovano je 1860. godine, dok je šumarska nastava počela iste godine u Križevcima. Društvena biblioteka je veoma bogata i posjeduje stručna djela, izdana na svim europskim jezicima.

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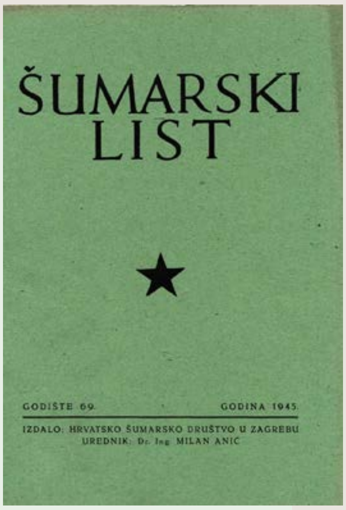
[1] Branko Meštrić, dipl. ing. šum., Hrvatsko šumarsko društvo

Ovaj tekst je prepričan dio zapisnika 66. redovite godišnje skupštine Hrvatskoga šumarskog društva iz Šumarskog lista 1-12/1945 s.75. Već u sljedećem broju Šumarskog lista, ime kojeg je nepromijenjeno još od 1877., nalazimo i zapis o održavanju izvanredne skupštine Hrvatskog šumarskog društva, koja je održana dana 23. ožujka 1946. god. u prostorijama društva Vukotinovićeva ulica br. 2. Na ovoj skupštini, nakon što je pročitan nacrt pravila i s manjim izmjenama jednoglasno prihvaćen, predsjednik Hrvatskog šumarskog društva prof. dr. Nenadić pita prisutne, da li prihvaćaju prijedlog da Hrvatsko šumarsko društvo uđe u sklop Društava inženjera i tehničara NR Hrvatske, te da kao Šumarska sekcija ovog novo-osnovanog društva nastavi svoj stručni rad. Prisutni izjavljuju da prihvaćaju prijedlog.

Tako je u novoj Jugoslaviji teško izboreno ime Hrvatsko šumarsko društvo uspjelo opstati cijelih 240 dana. No, 45 godina kasnije nestade i Jugoslavije a na 96. Skupštini Saveza društava inženjera i tehničara šumarstva i drvne industrije Hrvatske, na redovnom zasjedanju 20. lipnja 1991. godine, donesena je u Zagrebu odluka da se dosadašnji naziv organizacije mijenja u novi koji glasi: HRVATSKO ŠUMARSKO DRUŠTVO.

Hrvatsko šumarsko društvo je djelovalo u barem pet država i nekoliko društvenih sustava, pa nije čudno da je tijekom svoga postojanja promijenilo i silne nazive, no uvijek i usprkos svemu ostalo je **šumarsko**:

- Odsek za šumarstvo Družtva gospodarskoga za Hervatsku i Slavoniu, od 1846. do 1851.
- Družtvo šumarsko za Hrvatsku i Slavoniu, od 1851. do 1876.
- Hrvatsko - slavonsko šumarsko društvo, od 1876. do 1919.
- **Hrvatsko šumarsko društvo**, od 1919. do 1921.
- Jugoslavensko šumarsko udruženje, od 1922. do 1939.
- **Hrvatsko šumarsko društvo**, od 1939. do 1946.
- Šumarska sekcija Društva inženjera i tehničara Hrvatske, od 1946. do 1948.
- Sekcija šumarstva i drvne industrije Društva inženjera i tehničara Hrvatske, od 1949. do 1950.
- Šumarsko društvo NR Hrvatske, od 1950. do 1960.
- Savez šumarskih društava NR Hrvatske, od 1961. do 1964.
- Savez inženjera i tehničara šumarstva i drvne industrije Hrvatske, od 1964. do 1990.
- **Hrvatsko šumarsko društvo**, od 1991. nadalje



Šumarski list, časopis Hrvatskog šumarskog društva, tijekom gotovo stoljeća i pol neprekidnog izlaženja, u svim povijesnim i političkim razdobljima kroz koje je prolazila Hrvatska, ostao je neizbrisiva kronika hrvatskoga šumarstva i jedan od najstarijih znanstveno-stručnih i staleških šumarskih časopisa. Međutim, 69. godište iz 1945. godine nešto je posebno i treba o njemu potrošiti par riječi.
Svezak prije ovoga izašao je vjerojatno početkom 1945. pod nazivom Hrvatski šumarski list, kao izdavač je potpisano Hrvatsko šumarsko družtvo a uredio ga je prof. Josip Balen. Naravno, i simbol na naslovnici bio je malo drugačiji nego ovaj na slici desno. Nosio je oznaku 7-12/1944. Naravno, vremena su teška, ali šumari uspijevaju i u tim uvjetima izdati svoj časopis, pa makar kao šestobroj.
Slijedeća 1945. godina očito je bila još i problematičnija, ali eto ti našeg Šumarskog lista pod petokrakom zvijezdom, uređena po neprikosnovenom prof. Milanu Aniću i pod oznakom 1-12/1945. Da, izašao je kao **dvanaestobroj** - ali je izašao.
Iz ovog broja izvukli smo gornju „dramatičnu" bitku oko promijene naziva društva na 66. redovitoj godišnjoj skupštini, ali vrijedi spomenuti i ostali sadržaj:

– Na pragu novoga doba. - uvodnik
– Šuma u vjekovnoj borbi naših naroda za slobodu. - Dr. M. Anić
– Pogledi na šumsku vegetaciju Istre i susjednih zemalja. - Dr. M. Anić
– Paralela iz života i rada hrvatskog šumara J. Kozarca i ruskog šumara G. T. Morozova. - Dr. A. Petračić
– Развој шумарске политике у Совјетској Русији. - Др. А. Угреновић
– Prilozi pitanju šumarskog studija. - Dr. N. Neidhardt
– Bagremovi kolosjeci. - Dr. A. Petračić
– Sušenje drva. - Ing. R. Fantoni
– Kemijski način sušenja drvene građe. - Dr. J. Hribar
– Pojava zlatokraja i gubara u okolici Zagreba. - Dr. M. Anić
– O 22-godišnjici opstanka Šumskog vrta Poljoprivredno-šumarskog fakulteta u Zagrebu. - Dr. M. Anić
– Šumarska nastava u Savezu sovjetskih socijalističkih republika.

Ne možemo neprokomentirati - čak tri teme iz SSSR-a (jedna čak i na ćirilici, ipak je to 1945.) ali svakako i sasvim uredne znanstvene i stručne teme koje objavljuju profesori Šumarskog fakulteta, a ponajviše urednik dr. Milan Anić. Zgodno je primijetiti da su sažeci članaka dani na jednom od nekoliko jezika - engleskom, francuskom i ponajviše na ruskom.

Naravno, tu su zapisnici skupštine i sjednice Upravnog odbora koja joj je slijedila, objavljena su i nova Pravila Hrvatskog šumarskog društva, a također i vijesti iz društva. Nažalost i jedan nekrolog - ing. Ante Sedmak, načelnik u Ministarstvu šumarstva, aktivni sudionik rasprave na skupštini oko promijene imena, samo desetak dana iza skupštine „ubijen od zločinačke ruke" u Gorskom kotaru. Tako imamo u istom broju i njegovu diskusiju (za Šumarsko društvo Hrvatske), potom u zapisniku zabilježene počasti na sjednici upravnog odbora, a potom i njegov nekrolog.

Dr. sc. Antonio Vidaković

Igor Poljak[1]

Dr. sc. Antonio Vidaković, mag. ing. silv., obranio je 14. ožujka 2025. godine doktorski rad pod naslovom: „Morfološka i genetička raznolikost populacija i kemijski sastav plodova europske divlje kruške (*Pyrus pyraster* (L.) Burgsd.) i krušvine (*P. spinosa* Forssk.) u Hrvatskoj".

Javna obrana doktorskog rada održana je na Fakultetu šumarstva i drvne tehnologije Sveučilišta u Zagrebu, pred povjerenstvom u sastavu: prof. dr. sc. Marilena Idžojtić, Fakultet šumarstva i drvne tehnologije Sveučilišta u Zagrebu, predsjednica povjerenstva; prof. dr. sc. Zlatko Šatović, Agronomski fakultet Sveučilišta u Zagrebu, član povjerenstva; prof. dr. sc. Zlatko Liber, Prirodoslovno-matematički fakultet Sveučilišta u Zagrebu, član povjerenstva.

Disertacija je izrađena u Zavodu za šumarsku genetiku, dendrologiju i botaniku Fakulteta šumarstva i drvne tehnologije Sveučilišta u Zagrebu, pod mentorstvom izv. prof. dr. sc. Igora Poljaka. Rad je izrađen u sklopu Sveučilišnog poslijediplomskog doktorskog studija Šumarstvo i drvna tehnologija, uz financijsku potporu Sveučilišta u Zagrebu i u okviru znanstveno-istraživačkog projekta KK.01.2.2.03.0017 CEKOM 3LJ.

Disertacija je napisana na engleskom jeziku prema skandinavskom modelu te se sastoji od šest znanstvenih radova. Ukupnog je opsega 213 stranica, uključuje sedam priloga i sadrži 305 bibliografskih navoda. Rad je strukturiran u sedam poglavlja: Uvod, Pregled literature, Rasprava, Zaključci, Reference, Autorova biografija i Prilozi. Uz navedena poglavlja, disertaciji su priložene informacije o mentoru, zahvale, sažetak na engleskom jeziku, prošireni sažetak na hrvatskom jeziku, sadržaj te popis publikacija koje čine sastavni dio rada.

Životopis

Antonio Vidaković rođen je 16. ožujka 1995. godine u Fürstenfeldbrucku, Njemačka. Osnovno obrazovanje i opću gimnaziju završio je u Bjelovaru. Godine 2013. upisao je preddiplomski studij Urbano šumarstvo, zaštita prirode i okoliša na Fakultetu šumarstva i drvne tehnologije Sveučilišta u Zagrebu. Preddiplomski studij završio je obranom završnoga rada pod naslovom „Drvoredi Bjelovara", nakon čega je nastavio diplomski studij istoga smjera.

Diplomski studij završio je 2019. godine obranom diplomskoga rada pod naslovom „Kartiranje šumske vegetacije primjenom različitih metoda na primjeru Nacionalnog parka Risnjak". Tijekom diplomskog studija proveo je šest mjeseci na Erasmus studentskoj razmjeni na Sveučilištu za prirodne resurse i primijenjene znanosti (BOKU) u Beču, Austrija.

Dana 3. lipnja 2019. godine zaposlio se kao asistent u Zavodu za šumarsku genetiku, dendrologiju i botaniku Fakulteta šumarstva i drvne tehnologije Sveučilišta u Zagrebu, gdje izvodi vježbe iz kolegija Dendrologija za drugu godinu preddiplomskih studija Šumarstvo te Urbano šumarstvo, zaštita prirode i okoliša, kao i iz kolegija Osnove dendrologije za prvu godinu preddiplomskog studija Drvna tehnologija.

U akademskoj godini 2019./2020. upisao je poslijediplomski doktorski studij Šumarstvo i drvna tehnologija na Fakultetu šumarstva i drvne tehnologije Sveučilišta u Zagrebu, koji je završio 2025. godine. Suautor je 23 znanstvena i stručna rada te je sudjelovao na četiri nacionalna i četiri međunarodna znanstvena skupa.

Antonio Vidaković je član Dendrološke sekcije Hrvatskog botaničkog društva.

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Prošireni sažetak doktorskog rada

Divlja kruška (*Pyrus pyraster* (L.) Burgsd.) i krušvina (*P. spinosa* Forssk.) dvije su najčešće vrste divljih krušaka u Europi. Radi se o listopadnim, često trnovitim, heliofilnim, entomofilnim i zoohornim vrstama. Divlja kruška prirodno je rasprostranjena u južnoj, srednjoj i zapadnoj Europi, gdje raste pojedinačno ili u manjim skupinama uz rubove šuma i na zapuštenim poljoprivrednim površinama. Najčešće je element mješovitih hrastovo-grabovih, termofilnih hrastovih i nizinskih poplavnih šuma. S druge strane, krušvina raste u južnoj Europi, Maloj Aziji i na Bliskom istoku. Kserofitna je vrsta, koja obično raste na ekstremnim, suhim, toplim i degradiranim staništima. Za razliku od divlje kruške koju karakteriziraju okruglasti do jajasti listovi, krušvina ima uske i duguljaste listove koji podsjećaju na one u badema. Plodovi divlje kruške i krušvine su sličnih dimenzija, a najbolje se razlikuju po dužini stapke. Stapke plodova divlje kruške značajno su duže u odnosu na veličinu ploda, dok su u krušvine stapke i plodovi podjednako dugački. Obje vrste su od velikog značaja za bioraznolikost, budući da se mnogi sisavci i ptice hrane njihovim plodovima, a privlače i velik broj oprašivača. Unatoč tomu, kao i njihovom velikom potencijalu u šumarstvu te u prehrambenoj i farmaceutskoj industriji, ove su vrste do danas rijetko bile predmet znanstvenih istraživanja.

Divlja kruška i krušvina važni su sastavni dijelovi vaskularne flore u Hrvatskoj, gdje zauzimaju širok spektar ekoloških ništa. Divlja kruška je vrsta koju većinom nalazimo u kontinentalnom dijelu Hrvatske, dok je rijetka u submediteranskom području. S druge strane, krušvina raste u submediteranskoj i eumediteranskoj zoni duž jadranske obale. S obzirom na značaj ovih vrsta u pogledu biološke raznolikosti te njihove višestruke koristi, u ovoj disertaciji istražena je njihova genetička i fenotipska (morfološka i kemijska) raznolikost na području Hrvatske. Specifični ciljevi istraživanja bili su: (1) utvrditi genetičku i morfološku varijabilnost populacija divlje kruške i krušvine u Hrvatskoj; (2) utvrditi protok gena između prirodnih i kultiviranih populacija; (3) utvrditi prisutnost križanaca divlje kruške i krušvine te krušvine i običnog gloga; (4) testirati zavisnost genetičke i morfološke varijabilnosti u odnosu na ekološku i geografsku varijabilnost; i (5) utvrditi kemijski sastav plodova istraživanih vrsta i testirati njegovu zavisnost u odnosu na genetičku, morfološku i ekološku varijabilnost populacija.

Varijabilnost populacija na osnovi morfologije listova istražena je na biljnom materijalu sakupljenom iz 19 populacija divlje kruške i 17 populacija krušvine, pri čemu su u svakoj populaciji uzorci listova sakupljeni s deset stabala/grmova. U obje vrste utvrđena je velika varijabilnost morfoloških značajki listova, na unutar i međupopulacijskoj razini. Veći udio ukupne varijabilnosti odnosio se na unutarpopulacijsku, a manji na međupopulacijsku varijabilnost. Morfološke značajke lista koje su se odnosile na njegovu veličinu bile su varijabilnije od značajki povezanih s oblikom lista. Osim toga, pokazalo se da je morfologija listova divlje kruške i krušvine pod značajnim utjecajem okolišnih i geografskih čimbenika. Naime, uzorci izolacije uslijed okolišne udaljenosti i izolacije uslijed geografske udaljenosti pokazali su se statistički značajnima u oba slučaja, što znači da su geografski bliže populacije, kao i one koje rastu u sličnijim ekološkim uvjetima bile i morfološki sličnije. Populacije divlje kruške grupirale su se u dvije skupine, od kojih je prva većim dijelom uključivala jedinke submediteranskih populacija, a druga kontinentalnih. Općenito gledano, populacije submediteranske regije karakterizirali su listovi manjih dimenzija u odnosu na one iz kontinentalne regije. S druge strane, jedinke populacija krušvine grupirale su se u tri skupine, od kojih je prva uključivala stabla iz najsjevernijih i najjužnijih populacija, koje su karakterizirale visoke količine padalina. Navedene populacije u prosjeku su imale veće listove u odnosu na listove druge dvije skupine. Druge dvije skupine značajno su se preklapale, bez jasnog geografskog ili ekološkog uzorka. Osim stabala s tipičnim listovima, za ovu vrstu na području Istre i Dalmacije zabilježene su i jedinke su urezanim lišćem koje potencijalno mogu biti posljedica križanja krušvine s jednoplodničkim glogom (*Crataegus monogyna* Jacq.). Takav je križanac od ranije poznat u literaturi i nosi naziv ×*Pyrocrataegus*, no nedovoljno je istražen. Međutim, prisustvo heteroblastije u krušvine otežava interpretaciju ovih rezultata. Kako bi se došlo do konačnog zaključka, potrebna su daljnja istraživanja korištenjem markera DNA posebno dizajniranih za uporabu u oba roda.

Morfološka varijabilnost plodova, kao i njihov kemijski sastav (maseni udjeli vode, proteina, masti, pepela i šećera), istraženi su na temelju materijala sakupljenog sa 47 stabala iz devet populacija divlje kruške te 84 stabla/grma iz 10 populacija krušvine. Sve kemijske analize provedene su u skladu s AOAC (*Association of Official Analytical Collaboration*) protokolima i u duplikatima. U obje vrste utvrđena je značajna varijabilnost morfoloških i kemijskih značajki plodova, posebice na unutarpopulacijskoj razini. Prosječan plod divlje kruške bio je 2,3 cm dug i 2,7 cm širok, sa stapkom od 2,7 cm. Prosječna duljina i širina sjemenki bile su 6,3 i 4,2 mm. Svježi plodovi divlje kruške sadržavali su 70,7 % vode, 4,7 % fruktoze, 2,1 % glukoze, 0,91 % proteina, 0,65 % pepela i 0,25 % masti. S druge strane, plodovi krušvine u prosjeku su bili 2,1 cm dugi i 2,5 cm široki, sa stapkama od 2,0 cm. Sjemenke su u prosjeku bile 6,2 mm duge i 4,4 mm široke. Plodovi su sadržavali 68,9 % vode, 4,0 % glukoze, 3,0 % fruktoze, 1,0 % proteina, 0,74 %

pepela i 0,12 % masti. Korelacijska analiza pokazala je da su plodovi obje vrste pod značajnim utjecajem geografskih i okolišnih čimbenika. Naime, plodovi populacija divlje kruške s viših nadmorskih visina bili su u prosjeku manji i sadržavali su više fruktoze, u odnosu na plodove populacija s nižih nadmorskih visina. S druge strane, sjevernije populacije krušvine imale su kraće stapke, tanje sjemenke i niži sadržaj glukoze u odnosu na južnije populacije.

Genetička raznolikost populacija, stupanj hibridizacije između divlje kruške i krušvine te protok gena između kultiviranih i divljih krušaka istražen je na materijalu iz 21 populacije divlje kruške, 22 populacije krušvine te 24 kultivara pitome kruške. Za utvrđivanje genetičke raznolikosti korišteno je devet mikrosatelitnih biljega. Rezultati su pokazali visoku i relativno ujednačenu genetičku raznolikost populacija divlje kruške na području Hrvatske, kao i da su prirodne populacije divlje kruške u Hrvatskoj genetički raznolikije od onih u središnjoj Europi. S druge strane, genetička raznolikost populacija krušvine bila je nešto niža u odnosu na populacije divlje kruške. Vrijednosti genetičke diferencijacije izračunate između svih parova populacija upućivale su na veću međusobnu diferenciranost populacija divlje kruške u odnosu na one u krušvine. Nadalje, analizom molekularne varijance potvrđene su statistički značajne razlike između istraživanih vrsta, između populacija unutar svake vrste kao i unutar populacija. Analiza strukturiranosti populacija pokazala je da se sve istraživane jedinke uključene u ovo istraživanje mogu optimalno podijeliti u dva klastera; prvi koji je sadržavao jedinke divlje i pitome kruške, te drugi koji je sadržavao jedinke krušvine. Ukupno je u istraživanju identificirano 45 križanaca između divlje i pitome kruške, većina od kojih je pronađena u Istri i Slavoniji. Nadalje, u područjima gdje se ekološke niše divlje kruške i krušvine preklapaju, utvrđeno je 14 njihovih križanaca. Zabilježeno je i 10 križanaca između krušvine i pitome kruške. Rezultati Mantel testa pokazali su statistički značajnu korelaciju između genetičkih i geografskih udaljenosti u obje vrste, što znači da su geografski bliže populacije i genetički sličnije. S druge strane, nije utvrđena značajna korelacija između genetičkih i ekoloških udaljenosti.

U konačnici, dobiveni rezultati ove disertacije mogu poslužiti kao osnova za osnivanje konzervacijskih jedinica za očuvanje genetičke raznolikosti ovih dviju plemenitih šumskih voćkarica. S obzirom na to da su divlja kruška i krušvina vrste s malim brojem jedinki po populaciji te njihovom malom gustoćom, preporuka je osnivanje in situ konzervacijskih jedinica za njihovo očuvanje. Nadalje, populacije s najvećom genetičkom raznolikošću te one u kojima nije došlo do introgresije genoma pitome kruške u prirodne populacije mogu poslužiti kao temelj za osnivanje tih jedinica. Općenito gledano, važno je očuvati genske resurse divljih vrsta krušaka u Hrvatskoj kako bi se osigurala njihova održivost i potencijalna uporaba u budućim oplemenjivačkim programima. Očuvanje ovih genskih resursa ključno je za dugoročnu održivost i prilagodbu ovih vrsta na promjenjive ekološke uvjete.

Popis publikacija koje su sastavni dio disertacije

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- Vidaković A., Z. Šatović, Z. Liber, M. Jurica, I. Poljak, 2025: Leaf morphological variability of *Pyrus spinosa* and *Crataegus monogyna* and their potential hybridization. Acta Botanica Croatica 82 (2). https://doi.org/10.37427/botcro-2025-01

Objavljeni radovi predstavljaju vrijedan doprinos području istraživanja i rezultat su kontinuiranog rada, suradnje i znanstvene usmjerenosti. Uz iskrene čestitke na dosadašnjim postignućima, mladom kolegi želim puno uspjeha i nadahnuća u daljnjem znanstvenom razvoju!

NOVI SVEUČILIŠNI PRIRUČNIK

Matija Landekić, Marin Bačić, Josipa Nakić: Kultura sigurnosti u šumarstvu

Ivan Martinić[1]

Autori: Matija Landekić, Marin Bačić, Josipa Nakić
Izdavač: Sveučilište u Zagrebu Fakultet šumarstva i drvne tehnologije
Recenzenti: prof. dr. sc. Ivan Martinić, prof. dr. sc. Janez Krč, prof. dr. sc. Velid Halilović
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Sve ključno za razumijevanje sigurnog šumskog rada ovdje je, na jednom mjestu!

Zaista se rijetko u hrvatskom šumarskom znanstvenom i strukovno-praktičnom prostoru nailazi na objave udžbeničke ili priručničke građe iz područja sigurnosti pri šumskom radu. Posebice nema takvih objava na sveučilišnoj razini. U takvom nedostatku, ovomjesečna objava sveučilišnog priručnika „Kultura sigurnosti u šumarstvu - Postupci dobre prakse kod sječe i izrade drva" autora Matije Landekića, Marina Bačića i Josipe Nakić, više je nego dobrodošla.

Kako to navode autori u predgovoru, priručnik je jedan od praktičnih izvora za razumijevanje povezanosti pokazatelja razine sigurnosti u šumarstvu i ukupnosti rizika pri šumskom radu. Dalje navode kako postoje brojni mehanizmi koje je moguće praktično primijeniti kako bi se uspostavila kultura sigurnosti koja smanjuje rizike za sigurnost i zdravlje šumskih radnika. Dobra sigurnosna kultura prepoznaje da će se radna nezgoda vjerojatno dogoditi, pri čemu je glavni izazov za sve uključene kako izbjeći i/ili smanjiti posljedice.

U uvodnom poglavlju priručnika objašnjava se suodnos između šumarstva kao gospodarske djelatnosti i složenih rizika pri šumskim radovima. Uz naglašen radni rizik, u uvodu se pojašnjava teorijska osnova kulture sigurnosti. Pritom se iznose dosezi domaćih i međunarodnih relevantnih teorijskih znanja te različita područja modernih tehnologija koje zahtijevaju praktična rješenja u mnogim sigurnosnim područjima igledištima. Značaj kulture sigurnosti u operativnom šumarstvu veže se uz naglašavanje važnosti razvoja samosvijesti radnika da su oni „sami sebi najveća vrijednost".

U II. poglavlju „Ključni aspekti" obrazlaže se pristup uključivanja kulture sigurnosti u šumarstvo. Strukturirano se iznose metodološke upute za analizu postojećeg stanja, a potom i načini uvođenja trenutno najboljih rješenja u dnevni šumski rad. Korisnike djela upućuje se u konkretne mjere i postupke za osobno praktično angažiranje u različitim sigurnosnim izazovima i okolnostima, npr. pri izboru radnih metoda i sredstava/opreme, ili primjeni tehnika za povećanje interesantnosti i smanjenje monotonije pri radu. Poseban naglasak stavlja se na važnost hidracije organizma i ispravne prehrane šumskih radnika. Novina je prijedlog autora o primjeni „ergozagrijavanja" šumskih radnika, što podrazumijeva dnevnu rutinu razgibavanja i vježbanja prije

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posla radi podizanja indeksa radne sposobnosti. Unutar ovoga poglavlja obrađeni su i aspekti vezani uz važnost aktivnog i ispravnog korištenja osobne zaštitne opreme.

U III. poglavlju „Načela i postupanja" autori redovito koristeći grafičke prikaze iznose pregled nepravilnih i pravilnih posturalno-kretnih navika sjekača za odabrane elemente radne tehnike s ciljem smanjenja pojavnosti mišićno-koštanih problema. U cilju unapređenja radne sigurnosti pri sječi i izradi drva istaknuto je osam radnih postupanja, pri čemu se opisom i ilustracijama prikazuju slučajevi koji najčešće rezultiraju ozljedama te se navode pripadajuće mjera prevencije i postupanja kojima se rizik može umanjiti ili izbjeći. Radi podizanja svijesti profesionalnih šumskih radnika o vrstama, simptomima i mogućim zdravstvenim posljedicama od bioloških štetnosti, u priručniku nalazimo pregled mjera prevencije i sigurnosne procedure postupanja. U istom poglavlju posebno se pojašnjava važnost postupanja pri ozljedama te značaj izrade i poznavanja protokola postupanja u hitnim situacijama. U završnom dijelu poglavlja obrađuje se problematika sigurnosnih načela i mjera koje je neophodno uključiti u izradu akcijskog plana izvođenja šumskih radova pri sanaciji prirodnih nepogoda uzrokovanih vjetrom, snijegom, ledom ili poplavom.

Motorna pila kao osnovno sredstvo rada pri šumskom radu, predmet je bavljenja u IV. poglavlju „Ergonomija i inovacije", pri čemu se detaljno obrazlažu ključni aspekti ergonomske i sigurnosne pogodnosti. Poseban naglasak se stavlja na dizajn motorne pile (pozicioniranje ručki, masu, kontrole i dr.) te na štetnost za zdravlje radnika kakve su pri uporabi motorne pile vibracije, buka i ispušni plinovi. Nadalje se, u istom poglavlju, iznose smjernice dobre prakse koje se odnose na upute o periodičnosti održavanja motorne pile. Poglavlje se proširuje pregledom trendova razvoja u području humanizacije rada s usmjeravanjem na teme koje su izravno povezane s kulturom sigurnosti u operativnom šumskom radu. Upućuje se na četiri smjera razvoja ergonomskih inovacija za postizanje veće razine sigurnost pri šumskom radu: inovacije vezane za sredstva rada i pomoćni alat, (b) inovacije vezane za osobnu zaštitnu opremu, (c) inovativna rješenja za višu opću razinu sigurnosti i (d) tehnološko-inovativna rješenja tzv. industrije 4.0 u korist zaštite zdravlja radnika.

Završno V. poglavlje sadrži popis citirane literature, kazalo pojmova, pregled važnih datuma vezanih uz kulturu sigurnosti te kratki životopisi autora.

Posebnost priručnika su operativno primjenjivi brojni primjeri i ilustracije, te unutar svakog poglavlja zasebno istaknuti tekstovi „Jeste li znali?" i „Dobro je znati!" čime se dodatno pojačava pamtljivost tema koje se obrađuju.

Značajan broj obrađenih tema proizašao iz otvorenih

pitanja tekuće prakse šumskoga rada, što upućuje na posebnu potrebu prakse za priručnikom ovakve vrste, ponajprije u definiranju pristupa rješavanju problema i/ili unapređenja postojećeg stanja.

Aktualne strukovne spoznaje uključene u priručnik preuzete su iz građe koja čini stručne osnove postojeće razine organiziranosti funkcije sigurnosti pri šumskom radu u Hrvatskoj i u svijetu, gdje su važno gradivo u osposobljavanju šumskih radnika i usavršavanja inženjera šumarstva.

Odabirom tema i strukturom, priručnik je jednako namijenjen studentima, centrima za strukovno osposobljavanje, ali i stručnjacima u šumarskoj znanosti i praksi u različitim vidovima i razinama njihovog djelovanja. Značajni je doprinos građi za osposobljavanje i stručno usavršavanje inženjera u području šumarstva i sigurnosti. Također može biti dragocjeno gradivo instruktorima rada gdje se poštuje siguran način rada, posebno za poslove gdje se koristi motorna pila.

Nadamo se da će se ovim priručnikom dodatno potaknuti potreba žurne aktualizacije (čitaj: modernizacije) sektorske propisnosti u području sigurnosti pri šumskom radu, ponajprije današnjim vremenima u mnogočemu neodrživog Pravilnika o zaštiti na radu u šumarstvu, koji datira iz (pre)daleke 1986. godine!

Priručnik kojeg zbog njegove izrazito visoke kvalitete, ali i nesumnjive potrebe za takvim praktičnim pomagalom u svakodnevnoj šumarskoj proizvodnji najizravnije preporučam, biti će dostupan za nabavu krajem 2025. godine putem narudžbenice koja će biti objavljena na mrežnoj stranici FŠDT-a.

Uspješno služenje Priručnikom !

Šumarijade Federacije Bosne i Hercegovine

Oliver Vlainić[1]

Ove godine održana je 9. Šumarijada Federacije Bosne i Hercegovine. Tradicionalno natjecanje i druženje radnika u šumarstvu Federacije BiH održano je od 3. do 5. rujna 2025. u Sportsko-rekreacijskom centru Ajdinovići pokraj Olova. Domaćin ovogodišnje šumarijade bilo je Javno poduzeće „Šumsko-privredno društvo Zeničko-dobojskog kantona” d. o. o. Zavidovići. U organizaciji šumarijade uvijek sudjeluju strukovne udruge Udruženje inženjera i tehničara šumarstva FBiH i Hrvatsko šumarsko društvo u FBiH. Manifestacija se sastoji od natjecanja radnika šumarskih tvrtki i institucija u šumarskim i sportskim disciplinama, ali i od stručnog skupa i šumarskog kviza znanja. Natjecanje šumarskih radnika održava se po pravilima svjetskog natjecanja s disciplinama: obaranje stabla, okretanje vodilice, kombinirani prerez, precizno prepiljivanje trupca i kresanja grana. Nagrađuju se pojedinci i ekipe. Fakultativne discipline su presijecanje sjekirom, presijecanje amerikankom-ekipno te modeliranje motornom pilom i sjekirom. Sportske discipline su trčanje na 100 m (žene i muškarci), trčanje na 400 m (žene), trčanje na 800 m (muškarci), bacanje kugle (muškarci), skok u dalj (muškarci), trčanje u vreći na 20 m (žene), trčanje u vreći na 40 m (muškarci), streljaštvo (žene), obaranje s grede, potezanje konopca (žene i muškarci), šah, odbojka i mali nogomet. Ponekad se održavaju i revijalne malonogometne utakmice Šumarskog fakulteta u Sarajevu i direktora šumarskih tvrtki.

Šumarijada se održava svake druge godine na različitim mjestima. Prva šumarijada održana je 2008. godine u Sanskom Mostu, a domaćin je bilo Šumsko privredno društvo „Unsko-sanske šume” d. o. o. Bosanska Krupa.

Sudionici 5. šumarijade na Kupresu 2017. godine.

Nakon toga slijedile su šumarijade ovim redom: druga 2011. godine na Vlašiću (domaćin Šumskoprivredno društvo „Srednjobosanske šume” / Šumskogospodarsko društvo „Šume središnje Bosne” d. o. o. Donji Vakuf), treća 2013. godine u Zenici (domaćin Javno poduzeće „Šumsko-privredno društvo Zeničko-dobojskog kantona” d. o. o. Zavidovići), četvrta 2015. godine na Bjelašnici (domaćin Kantonalno javno poduzeće „Sarajevo šume” d. d. Sarajevo), peta 2017. godine na Kupresu (domaćin Šumsko gospodarsko društvo „Hercegbosanske šume” d. o. o. Kupres), šesta 2019. godine u Tuzli (domaćin Javno poduzeće „Šume Tuzlanskog kantona” d. d. Kladanj), sedma 2021. godine u Bosanskoj Krupi (domaćin Šumsko privredno društvo „Unsko-sanske šume” d. o. o. Bosanska Krupa) i osma 2023. godine na Vlašiću (domaćin Šumskoprivredno društvo „Srednjobosanske šume” / Šumskogospodarsko društvo „Šume središnje Bosne” d. o. o. Donji Vakuf). Osim navedenih

Pozdravni govor predsjednika HŠD Olivera Vlainića na 5. šumarijadi na Kupresu 2017. godine.

Obaranje s grede na 6. šumarijadi u Tuzli 2019. godine.

[1] Oliver Vlainić, dipl. ing. šum., Hrvatsko šumarsko društvo

Sudionici 7. šumarijade u Bosanskoj Krupi 2021. godine.

Tajnik UŠIT FBIH Azer Jamaković i dopredsjednica HŠD Mandica Dasović na 8. šumarijadi na Vlašiću 2023. godine.

domaćina u šumarijadama sudjeluju i predstavnici Kantonalne javne ustanove za zaštićena prirodna područja kantona Sarajevo, Šumarstva „Prenj" d. d. Konjic, Javnog poduzeća „Bosansko-podrinjske šume" d. o. o. Goražde, Šumarskog fakulteta Sveučilišta u Sarajevu, Samostalnog sindikata šumarstva, prerade drveta i papira BiH te srednjih šumarskih škola. Česti gosti su šumarske delegacije iz Republike Turske s kojima šumarstvo FBiH ima jako razvijene međusobne odnose. Na ceremonijama otvaranja i zatvaranja manifestacije nazočni su predstavnici federalne i kantonalne vlasti nadležne za sektor šumarstva. Tom prilikom nastupaju i lokalna kulturno-umjetnička društva. Zainteresirani dobavljači opreme za šumarstvo izlažu svoju ponudu, a sponzorstvima pomaže i drvna industrija. U večernjim satima organiziraju se zabavni programi i zajednička druženja svih sudionika.

Stručni skupovi se sastoje od javnih rasprava o aktualnostima u struci, prezentacija knjiga i priručnika. Na skupovima sudjeluju predstavnici znanosti i struke iz FBiH, ali i gosti iz inozemstva. Hrvatsko šumarsko društvo sa svojim predstavnicima nazočno je na šumarijadama od 2017. godine kada je održana 5. šumarijada na Kupresu. Poziv za sudjelovanje upućivale su obje strukovne udruge FBiH te s dužnom pažnjom i ljubaznošću dočekivale goste iz Hrvatske. U pojedinim godinama na šumarijadama su bili i predstavnici pojedinih podružnica Hrvatskih šuma. Svoj obol sudjelovanju predstavnici HŠD-a dali su kroz pozdravne govore na otvorenjima manifestacije, završnu podjelu nagrada, razmjenu stručnih publikacija, aktivno učešće u stručnim skupovima te razmjenu iskustava u neformalnim druženjima s raznolikim sudionicima šumarijade. Saznanja se dopunjuju i upoznavanjem s kulturno-povijesnim nasljeđem područja u kojemu se šumarijade održavaju.

Hrvatski predstavnici na 8. šumarijadi na Vlašiću 2023. godine.

Natjecanje šumarskih radnika na 8. šumarijadi na Vlašiću 2023. godine.


Posjet zaštićenom pejzažu Bijambare 2025. godine.

Treći ljetno-sportski susret šumara Alpe-Adria na Rabu

Oliver Vlainić[1]

Treće ljetno natjecanje šumara regije Alpe-Adria ovaj je put održano u jesenskom terminu (zbog cjenovno povoljnijih posezonskih uvjeta) od 3. do 5. listopada 2025. na otoku Rabu. Ukupno to je dosada 29. izdanje susreta Alpe-Adria što znači da 2026. godine slijedi jubilarno 30. natjecanje i druženje. Organizator susreta bio je delnički ogranak HŠD-a. Na ovogodišnje okupljanje odazvalo se osamdesetak sudionika iz dviju talijanskih regija Južnog Tirola i Furlanije-Julijske krajine te Slovenije i Hrvatske. Prvoga dana poslijepodne po sunčanom, ali vjetrovitom vremenu, održano je trkačko natjecanje. U ženskoj konkurenciji u utrci na 2,5 km prva dva mjesta pripala su natjecateljicama iz Furlanije-Julijske krajine dok je treće mjesto osvojila predstavnica Južnog Tirola. Muškarci su bili podijeljeni u dvije starosne kategorije. U kategoriji mlađih muškaraca do 55 godina u utrci na 5 km prvo i treće mjesto osvojili su trkači Furlanije-Julijske krajine, a između njih na drugom mjestu bio je slovenski predstavnik. Među starijim muškarcima preko 55 godina u utrci na 2,5 km prva dva mjesta pripala su trkačima Furlanije-Julijske krajine, a treće mjesto je osvojio hrvatski predstavnik Goran Bukovac. U večernjim satima pod reflektorima boćališta Društva sportske rekreacije Kampor boćalo je ukupno 14 ekipa. Usprkos hladnijem vremenu uz glazbu i dovoljnu količinu pića za zagrijavanje vladala je dobra atmosfera. Do polufinala probile su se četiri hrvatske ekipe koje su u međusobnom razigravanju okončale natjecanje tek iza ponoći. Prvo mjesto osvojila je ekipa Hrvatske 1 u sastavu Darija Damić Piskač, Marko Piskač i Josip Afrić. Drugo mjesto pripalo je ekipi Hrvatske 3 koju su činili Kristina Herljević, Ana Frlan i Eugen Brozović. Treće mjesto zaslužila je ekipa Hrvatske 4 u sastavu Darijo Cenčić, Neven Vukonić i Tijana Grgurić. Bez medalje na četvrtom mjestu ostala je ekipa Hrvatske 2, a u njoj su nastupili Iva Kauzlarić, Melita Malnar i David Crnić.

Trčanje.

[1] Oliver Vlainić, dipl. ing. šum., Hrvatsko šumarsko društvo


Zimski uvjeti na boćanju pod reflektorima.


Potezanje konopa.

Drugoga dana po toplijem vremenu na području Nastavno-pokusnoga šumskog objekta Rab prvo je održano natjecanje u timskom triatlonu gdje su tri muško-ženska natjecatelja morali u moru preplivati 200 m, pretrčati 1 km i odvoziti biciklom 5 km. Sudjelovalo je 12 ekipa. Usprkos velikoj prednosti ekipe Hrvatske 1 nakon plivanja i trčanja zahvaljujući bržoj biciklističkoj etapi prva dva mjesta pripala su ekipama Slovenije 1 i Slovenije 2, dok je treće mjesto osvojila ekipa Furlanije-Julijske krajine 1. Ekipa Hrvatske 2 zauzela je šesto, ekipa Hrvatska 1 sedmo i ekipa Hrvatska 3 jedanaesto mjesto. Nastavak natjecanja donio je za publiku najuzbudljivije dinamično nadmetanje četiri ekipe u povlačenju konopa koje je bilo popraćeno bučnim navijanjem. Zahvaljujući snazi u toj disciplini dominirala je ekipa Hrvatske te u sastavu: Josip Afrić, David Crnić, Dario Cenčić, Marko Piskač, Snježana Križ i Melita Malnar uvjerljivo savladala sve ostale ekipe. Ekipi Južnog Tirola,


Triatlon - plivanje u moru.

pojačanoj s hrvatskim predstavnicima Kristinom Herlje-vić i Nenadom Aleksićem, pripalo je drugo mjesto, ekipi Slovenije treće, a ekipi Furlanije-Julijske krajine četvrto mjesto. Nakon odličnog gulaša od muflona dopunjenog s tjesteninom završna disciplina bila je odbojka na pije-sku. Između 11 ekipa prvo mjesto pripalo je ekipi Slovenije 2, drugo mjesto ekipi Slovenije 1 te treće mjesto ekipi Hrvatske 1 (Darija Damić Piskač i Marko Piskač).

Budući da su ljetni susreti Alpe-Adria u Hrvatskoj nadomjestak za zimske susrete, veća težina u bodovanju dodijeljena je trčanju kao zamjeni skijaškom trčanju i timskom triatlonu kao zamjeni skijaškoj štafeti (skijaško trčanje i veleslalom). Zahvaljujući tome i velikom broju osvojenih bodova u trčanju ukupni pobjednik bila je ekipa Furlanije-Julijske krajine. Na drugo mjesto, zahvaljujući dobrim rezultatima u trčanju, triatlonu i odbojci, plasirala se ekipa Slovenije. Domaća ekipa Hrvatske zauzela je treće mjesto usprkos pobjedi u potezanju konopa i prva četiri mjesta u boćanju. Posljednje četvrto mjesto pripalo je ekipi Južnog Tirola koja je bila i najmalobrojnija među svim sudionicima.

Priznanja za prva tri mjesta u svim disciplinama te ukupno za ekipe podijeljena su drugu večer u rapskom hotelu International. Ekipe su po dobrom običaju međusobno podijelile i darove. Sudionici susreta nakon toga imali su priliku zabaviti se na turističkoj manifestaciji Kanata koja se svake godine održava u Rabu na kraju turističke sezone.

Posljednjeg dana tjerani kišom i jugom sudionici su se nakon doručka uputili svojim kućama. Fakultativni obilazak i upoznavanje sa znamenitostima otoka Raba ostavljeni su za neku drugu prigodu. I bez toga dojmovi druženja i natjecanja su odlični, a dobar dio sudionika će se vidjeti u siječnju sljedeće godine na 56. EFNS natjecanju u Italiji.

Glavni obol organizaciji trećih ljetno-sportskih susreta Alpe Adria od pripreme do realizacije, ali i kao uspješni natjecatelji, dali su predsjednik delničkog ogranka HŠD-a David Crnić i član istoga ogranka Goran Bukovac. Veliki doprinos dao je upravitelj Šumarije Rab i predsjednik senjskog ogranka Boris Belamarić, koji je osim pomoći u provedbi organizacije, prvi put sudjelovao na Alpe-Adriji kao odličan natjecatelj u plivanju. Donacijama i logistikom pomoć u organizaciji pružili su Fakultet šumarstva i drvne tehnologije iz Zagreba, delnička podružnica Hrvatskih šuma d. o. o., Šumarija Rab, Društvo sportske rekreacije Kampor i središnjica HŠD-a.

Zajednička fotografija svih sudionika susreta Alpe-Adria.

ANTON PRELESNIK (1934. - 2025.)

Damir Delač[1]

Foto: In memoriam: Anton Prelesnik. Gozdarski vestnik, Ljubljana

18. srpnja 2025. u 91. godini života preminuo je Anton Prelesnik, dipl. ing. Radio je u Šumarsko-gospodarskom području Kočevje u Sloveniji. Cijeli njegov životni put bio je usmjeren ka šumi. Već kao petnaestogodišnji dječak sudjelovao je u izmjeri šuma Kočevskoga roga. Nakon završetka studija šumarstva bio je jedan od prvih poslijeratnih diplomiranih inženjera u kočevskom kraju, a kasnije, u to doba, i jedan od rijetkih koji je završio poslijediplomski studij i postao specijalist u području šumarstva.

Mnogi posjetitelji Kočevskoga kraja iz cijeloga svijeta sjećaju se njegovih stručno vođenih obilazaka, tijekom kojih je svojim velikim znanjem, iskustvom i ljubavlju predstavljao prirodu i povijest ovoga kraja.

Svoje znanje o šumama i povijesti svoga kraja objavio je u brojnim prilozima u stručnim časopisima i predavanjima na stručnim seminarima. Posebice je rado svoja znanje prenosio na najmlađe.

Između ostalog, osnovao je poznatu Rošku pešpot (Rošku pješačku stazu), a po njemu je nazvana i prirodna znamenitost Prelesnikova Koliševka.

Za svoj rad na očuvanju kulturne i prirodne baštine primio je brojna priznanja te je proglašen i počasnim građaninom općine Kočevje, a u dokumentarnom filmu „Tajne kočevske šume" prikazan je i njegov rad.

Aktivno je sudjelovao i na šumarskim sportskim susretima EFNS i AlpeAdria. Na tim se susretima uvijek rado družio s nama Hrvatima, naglašavajući kako je rođen na Sušaku. U svakom razgovoru vraćali smo se šumi, a meni je osobno jako žao što nismo ostvarili njegov prijedlog „Pripelji kolege iz Hrvaške in skupaj se bomo sprehodili in filozofirali o gozdu" (Dovedi kolege iz Hrvatske pa ćemo zajedno šetati i filozofirati o šumi).

Anton Prelesnik ostat će u našem sjećanju kao vrsni šumar, dobar kolega i čovjek.

[1] Mr. sc. Damir Delač, Hrvatsko šumarsko društvo

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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Slika 1. Kivi u Fažani. ☐ Figure 1 Kivifruit in Fažana (Croatia).

Slika 2. Listovi su naizmjenični, jednostavni, široko jajasti do okruglasti, napiljenog ruba, srcaste osnove, 8–12 cm dugački i široki, peteljka je 3,5–7,5 cm dugačka. ☐ Figure 2 Leaves are alternate, simple, broadly ovate or suborbicular, with serrate margins and cordate base, upper surface is dark green, lower white hairy, 8–12 cm long and wide, petiole is 3.5–7.5 cm long.

Slika 3. Cvjetovi su funkcionalno dvodomni, jednospolni, entomofilni, uresni, mirisni, 2,5–5 cm promjera; cvjetanje je u svibnju i lipnju, nakon listanja. ☐ Figure 3 Flowers are functionally dioecious, unisexual, entomophilous, conspicuous, fragrant, 2.5–5 cm in diameter; flowering in May to June, after leaves.

Slika 4. Bobe su elipsoidne, žućkastosmeđe do smeđe, gusto obrasle kratkim, čvrstim, smeđim dlačicama, 4–6 cm dugačke, 3 cm promjera, sadrže brojne sjemenke; mesnati dio ploda je mekan, sočan, zelen, sjajan, sladak do slatkasto kisel, jestiv; plodovi dozrijevaju u studenom i prosincu, 6–7 mjeseci nakon cvjetanja, zoohorni su. ☐ Figure 4 Berries are ellipsoid, yellowish-brown to brown, densely covered with short, stiff, brown hairs, 4–6 cm long, 3 cm in diameter, many-seeded; flesh is soft, juicy, green, glistening, sweet to sweetly sour, edible; maturing in November to December, 6–7 months after flowering, zoochorous.

Actinidia chinensis var. *deliciosa* (A.Chev.) A.Chev. (*A. deliciosa* (A.Chev.) C.F.Liang et A.R.Ferguson) – kivi (Actinidiaceae)

Rod *Actinidia* Lindl. sadrži više od 50 vrsta drvenastih povijuša i grmova, rasprostranjenih u istočnoj Aziji. Kivi je listopadna, 5–10 m visoka povijuša, čije je područje prirodne rasprostranjenosti južna Kina. Prve sjemenke kivija su iz Kine u Novi Zeland donesene 1904. godine. U Novom Zelandu je zatim selekcioniran ženski kultivar 'Hayward' te je započeo komercijalni uzgoj plodova. Kultivar 'Hayward' je do danas ostao komercijalno najčešće uzgajani kultivar kivija. Osim u novom Zelandu, kivi se komercijalno uzgaja u mnogim zemljama, kao npr. Kini, Italiji, Čileu, SAD-u i dr. Također se često uzgaja i u Hrvatskoj. Za dozrijevanje plodova potrebno je dugo, toplo ljeto. Mladi izbojci i cvjetni pupovi osjetljivi su na kasne proljetne mrazove. Budući da je kivi funkcionalno dvodomna vrsta, za dobivanje plodova potrebno je posaditi i ženske i muške biljke.

Actinidia chinensis var. *deliciosa* (A.Chev.) A.Chev. (*A. deliciosa* (A.Chev.) C.F.Liang et A.R.Ferguson) – Kiwifruit, Chinese Gooseberry (Actinidiaceae)

The genus *Actinidia* Lindl. comprises over 50 species of woody twining vines and shrubs, distributed in eastern Asia. Kiwifruit is a deciduous, 5–10 m tall twining vine, native to southern China. The first kiwifruit seeds were brought from China to New Zealand in 1904, where the female cultivar 'Hayward' was selected and the commercial fruit production was developed. This cultivar still accounts for a large proportion of traded kiwifruit today. Besides New Zealand, kiwifruit is commercially grown in many countries, such as China, Italy, Chile, USA, etc. It is also widely grown in Croatia. Plants require long warm summer in order to ripen the fruit. Young shoots and flower buds are vulnerable to late spring frosts. Kiwifruit is functionally dioecious species. For fruit production, both female and male plants are required.

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