Slovensko **agronomsko društvo**

Slovenian Society of Agronomy

Novi izzivi v agronomiji 2025

PROGRAM SIMPOZIJA
IN POVZETKI PREDAVANJ

New challenges in agronomy 2025

SYMPOSIUM PROGRAM
AND SUMMARIES

Laško 2025

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NEW CHALLENGES IN AGRONOMY 2025

SYMPOSIUM PROGRAM AND SUMMARIES

Laško, 2025

Simpozij Novi izzivi v agronomiji 2025 z mednarodno udeležbo
Laško, 30. in 31. januar 2025

PROGRAM SIMPOZIJA IN POVZETKI PRISPEVKOV, ki niso objavljeni v zborniku kot celotni prispevki

Uredniki (po abecednem vrstnem redu):
dr. Barbara Čeh, dr. Peter Dolničar, Boštjan Ferenčak, prof. dr. Denis Stajnko, dr. Igor Šantavec in Igor Škerbot

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KAZALO

Varstvo rastlin

Zelišča

Vpliv rastnih razmer

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10.00–10.30 **The impact of ecological intensification and crop-livestock integration in farming systems on soil health**
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Azra Šabić, Mateja Grašič in Irena Bertoncelj

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Kristina Ugrinović

29 Biotično zatiranje invazivnega plevela pelinolistne ambrozije (*Ambrosia artemisiifolia* L.) s hroščem ambrozijevim lepencem (*Ophraella communa* LeSage) (Coleoptera)
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15.15–15.45 **Odmor za kavo in ogled posterjev**

Kmetijstvo širše. Moderatorja: dr. Igor Šantavec in Igor Škerbot

15.45–16.00 **Povezovanje znanja in učenja v skupnosti prakse za varnost in zdravje pri delu kmetov**
Majda Černič Istenič in Mateja Slovenc Grasselli

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17.15–17.30 **Modeliranje kmetijskih ukrepov za varovanje podzemnega habitata črne človeške ribice pred onesnaževanjem z nitrati**
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Barbara Pipan, Lovro Sinkovič in Vladimir Meglič

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Povzetki prispevkov, ki niso objavljeni v zborniku simpozija

Gospodarske in okoljske koristi združevanja več senzorskih podatkov za natančno upravljanje naravnih virov kmetijstva

Abdul M. MOUAZEN[1]

Tradicionalno se lastnosti tal in pridelka določajo s pomočjo omejenega števila vzorcev, ki se analizirajo v laboratoriju. Povečanje števila vzorcev, potrebnih za opredelitev variabilnosti znotraj parcele, ni smiselno zaradi dodatnega dela, časa in stroškov. Orodja za proksimalno in daljinsko zaznavanje so se izkazala za uporabne tehnologije zaznavanja za kartiranje prostorske variabilnosti posameznih lastnosti, ki so potrebna za podporo odločanju pri variabilnih aplikacijah določenih materialnih virov. V članku so predstavljene ugotovitve o potencialu izbranih tehnologij zaznavanja in združevanja podatkov za optimizacijo tehnologij s spremenljivimi odmerki v pridelavi poljščin. Govori o rezultatih uporabe simulacijskih in terenskih poskusov z variabilno aplikacijo, izvedenih v več kot 10-ih letih v različnih evropskih državah. Rezultati uporabe aplikacij s spremenljivimi odmerki so v največji meri pokazali, da so v primerjavi s tradicionalnimi aplikacijami z enotnimi odmerki povečali pridelek in dobičkonosnost, hkrati pa zmanjšali vpliv na okolje z zmanjšanjem količin agrokemikalij. Zato se priporoča spodbujanje uporabe ključnih tehnologij proksimalnega in daljinskega zaznavanja v obliki združenega modeliranja v integriranem sistemu, namenjenem odločanju, saj so agronomske, gospodarske in okoljske koristi zelo obetavne.
Kljub vsem doseženim napredkom v razvoju tehnologij za aplikacije, namenjenem preciznemu kmetijstva, praktična uporaba s strani kmetom močno zaostaja. To je najbolj zahtevno vprašanje, na katero je potrebno najti odgovor, saj bi lahko naložbe v precizno kmetijstvo kmetom prinesle tudi nove tehnologije pridelave. Vendar pa obstaja več težav, ki ovirajo sprejetje, vključno s kompleksnostjo rešitev, drago tehnologijo in odsotnostjo sistema za podporo odločanju, ki bi omogočal napoved donosnosti novi tehnologij pred nakupom. Čeprav je dobičkonosnost glavni razlog, da kmetje sprejmejo novo tehnologijo, so okoljske koristi in trajnost, ki jih dosegamo s preciznim kmetijstvom, še en dejavnik, ki ni le v interesu kmetov, ampak tudi oblikovalcev kmetijske politike.

Ključne besede: proksimalno zaznavanje tal, precizno poljedelstvo, združevanje podatkov, simulacija, terenski poskusi

[1] Prof., PhD, Department of Environment, Ghent University, Gent, Belgium, e-mail: abdul.mouazen@ugent.be

Economic and environmental benefits of multi-sensor data-fusion for precision management of farming input resources

Traditionally, soil conditions and crop characteristics are determined by a limited number of samples that are analysed in the laboratory. Increasing the number of samples, necessary to characterise the within-field variability, is prohibited by the extra effort, time and costs involved. Proximal and remote sensing tools have been shown to be useful sensing technologies for mapping the spatial variability necessary for decision support of variable rate applications. This paper presents recent findings about the potential of selected sensing technologies and their data fusion for optimising variable rate applications in arable crop production. Results for variable rate applications of both simulation and field experiments carried out in more than 10 years in different European and associated countries are reported. Results showed, in the top majority of cases, that compared to the traditional uniform rate applications, variable rate applications increase crop yield, and profitability, while reduce environmental impact by decreasing the amount of agrochemicals. It is recommended to promote the adoption of key proximal and remote sensing technologies and fusion modelling in an integrated decision support system as the agronomic, economic and environmental benefits are promising.
With all advances made in the technology development for precision agriculture applications, the adoption rate by farmers lags behind. This is the most appealing issue that should be tackled so that the investment in precision agriculture can bring new technologies into the farmer's hand. However, there are several issues that hinders the adoption, including complexity of the solution, expensive technology, and absence of a decision support system that enable the prediction of framer profitability ahead of adopting it. Although profitability is the main derive for farmers to adopt the technology, environmental benefits and sustainability achieving by precision agriculture is another factor that is not only of farmers' interest but of ultimate one to the policy makers.

Keywords: proximal soil sensing, precision agriculture, data fusion, simulation, field experiments

Vpliv ekološke intenzifikacije in integracije poljedelstva ter živinoreje v kmetijske sisteme na zdravje tal

Andreas GATTINGER[2]

Na svetu se več kot 90 % vse hrane pridela v tleh. Kljub ključni vlogi tal so le-ta ogrožena na globalni, evropski in nacionalni ravni. Ekološka in funkcionalna intenzifikacija poljedelstva ter zapiranje kroženja hranil z integracijo pridelave rastlin in živinoreje veljata za najboljši praksi pri usklajevanju kmetijske produktivnosti z zdravjem tal, ekosistemov in celo zdravjem ljudi ("*One Health*" koncept).
Integracija ekoloških procesov v upravljanje agroekosistemov lahko zmanjša odvisnost od mineralnih gnojil z vključevanjem metuljnic v pridelovalne sisteme. Ta praksa je pogosta v ekološkem kmetijstvu in vpliva na dinamiko pretvorbe dušika v tleh. Ekološki kmetijski sistemi imajo pogosto večjo vsebnost organskega ogljika v tleh, kar vpliva na lastnosti rastlin ter povečuje številčnost in aktivnost mikroorganizmov v tleh. Integracija poljedelstva in živinoreje, zlasti v obliki mešanih kmetij, je ključen element ekološkega kmetijstva, saj podpira kroženje hranil in upravljanje organske snovi. Mešano kmetijstvo temelji na naravnih procesih, kot sta kroženje hranil in organske snovi med metuljnicami za krmo v kolobarju in uporaba živinskih gnojil. Živinska gnojila so dragocen vir dušika za rast rastlin in lahko izboljšajo vsebnost organskega ogljika ter mikrobiološko aktivnost tal. Ti dejavniki prispevajo k večjim pridelkom v ekoloških sistemih in zmanjšujejo pridelovalno vrzel v primerjavi s konvencionalnim kmetijstvom.
Dolgoletne študije kažejo, da ekološki kmetijski sistemi povečujejo pestrost bakterij v tleh in vplivajo na sestavo mikrobnih združb v primerjavi s konvencionalnimi sistemi. V ekoloških sistemih je pogosto izboljšana tudi sposobnost nitrifikacije in zaznavno zmanjšanje emisij dušikovega oksida. Nasprotno pa ekološko kmetovanje brez živali, ki izključuje živalske organske dodatke, močno temelji na dodajanju hranil z rastlinami. To vključuje vključevanje metuljnic, vmesnih posevkov, komposta in ostankov pridelkov za ohranjanje zaloge hranil in vsebnosti organske snovi v tleh. Vendar se takšen način kmetovanja sooča z izzivi pri doseganju primerljivih pridelkov v primerjavi s kombinirano poljedelsko-živinorejsko in poljedelsko pridelavo. Izbira med kombinirano poljedelsko-živinorejsko usmeritvijo in pridelovanjem poljščin brez živali v ekološkem kmetijstvu je odvisna od različnih dejavnikov, vključno s tipom tal, podnebjem in željenimi ekosistemskimi storitvami. Čeprav mešano kmetijstvo z živinorejo ponuja prednosti pri kroženju hranil in stabilnosti pridelkov, je ekološko kmetijstvo brez živali s kolobarjem z lucerno možna alternativa za vzpostavitev trajnostnih in produktivnih ekoloških sistemov.
Predavanje bo ponudilo vpogled v najnovejše raziskave na to temo ter obravnavalo raziskovalne in znanstvene vrzeli za razvoj podnebno odpornih sistemov kmetovanja na tleh v okviru planetarnih meja.

Ključne besede: kakovost tal, agroekologija, ekološko kmetijstvo, dolgoletni poskusi, sekvestracija C, emisije TGP, sestava mikrobnih združb

[2] Prof. PhD, Justus-Liebig University Giessen, Germany, e-pošta: andreas.gattinger@agrar.uni-giessen.de

The impact of ecological intensification and crop-livestock integration in farming systems on soil health

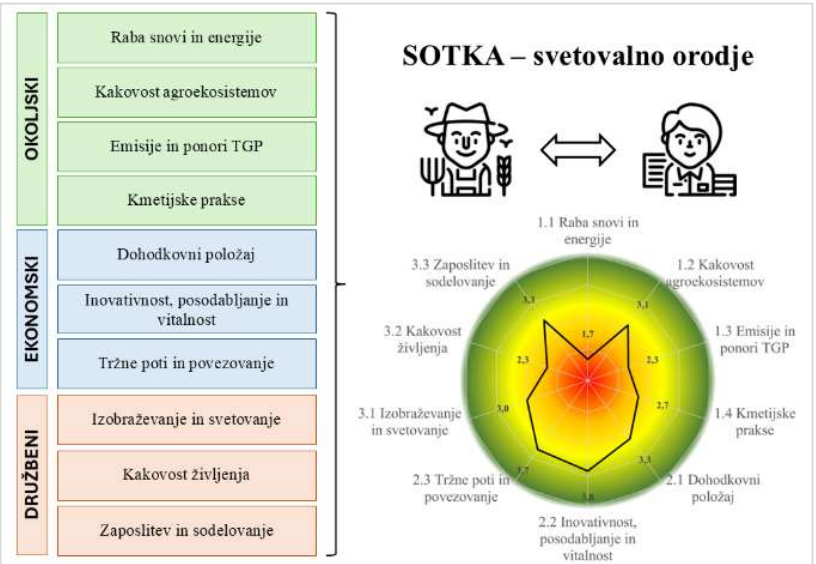
More than 90% of worlds food derives from “soil-based” agriculture. Despite of this essential role, soils are under threat at global, European and national levels. Ecological and functional intensification of arable farming, along with closing the nutrient loop through the integration of crop and livestock production are considered as best practice examples to reconcile agricultural productivity with soil, ecosystem or even One Health.
Integrating ecological processes into agroecosystem management can reduce reliance on mineral fertilizers by incorporating legumes into cultivation systems. This practice is common in organic farming, and impacts soil nitrogen transformation dynamics. Organic farming systems often have higher soil organic carbon content, influencing plant traits and increasing microbial abundance and activity in the soil. Crop-livestock integration, particularly mixed farming, is a key element of organic farming, supporting nutrient cycling and organic matter management. Mixed farming relies on natural processes like nutrient and organic matter cycling between legume forage in the crop rotation and the application of animal manure. Animal manure is a valuable source of nitrogen for plant growth and can enhance soil organic carbon and microbial activity. These factors contribute to higher yields in organic systems and reduce the yield gap compared to conventional agriculture.
Long-term studies show that organic farming systems enhance soil bacterial richness and influence community structure compared to conventional systems. The capacity for nitrification and nitrous oxide reduction is also often enhanced under organic management. In contrast, stockless organic farming, which excludes animal-derived organic amendments, relies heavily on plant-based fertilizer management. This involves incorporating leguminous crops, catch crops, compost, and crop residues to maintain nutrient cycling and soil organic matter content. However, stockless farming can face challenges in achieving comparable yields to mixed systems. Ultimately, the choice between mixed farming and stockless farming in organic agriculture depends on various factors, including soil type, climate, and desired ecosystem services. While mixed farming with livestock offers advantages in terms of nutrient cycling and yield stability, stockless farming with rotational alfalfa ley can be a viable alternative to achieve sustainable and productive organic systems. This lecture will give insights into latest research on this topic and will also tackle research and knowledge gaps towards climate-resilient soil-based farming systems within the planetary boundaries.

Keywords: soil quality, agroecology, organic agriculture, long-term experiments, Carbon sequestration, GHG emission, microbial community composition

SOTKA - Slovenski sistem za oceno trajnosti kmetije: Metodologija in rezultati testiranja

Rok MIHELIČ[3], Ana SCHWARZMANN in Jure ČOP

V svetu so razviti številni sistemi ocenjevanja trajnosti kmetij, med katerimi so nekateri generični, drugi pa prilagojeni specifičnim pridelovalnim in socio-ekonomskim razmeram nekega območja. Zaradi omejenih možnosti uporabe tujih sistemov ocenjevanja trajnosti v slovenskem kmetijstvu smo razvili sistem SOTKA (sistem za oceno trajnosti kmetovanja), ki je prilagojen našim razmeram in hkrati enostaven za uporabo. Osnova za razvoj sistema SOTKA je bil generičen sistem SAFA (Sustainability Assessment of Food and Agriculture Systems, FAO). Sistem SOTKA sestavlja 55 indikatorjev, od tega 31 okoljskih, 14 ekonomskih in 10 družbenih, ki so natančno opredeljeni in opremljeni z ocenjevalno lestvico z opisom ocen trajnosti. Pri ocenjevanju trajnosti kmetije se ocene na ravni indikatorjev vnese v aplikacijo, ki samodejno generira grafikone trajnosti kmetije po tematskih področjih, ločeno za okoljski, ekonomski in družbeni vidik. Prikaže tudi poligon z ocenami trajnosti za vsa tematska področja, ki je osrednji vizualni rezultat trajnostne analize kmetije. Razlaga trajnosti kmetije temelji na povprečnih ocenah tematskih področij in ocenah po posameznih indikatorjih. Poročilo o celoviti oceni trajnosti kmetije, ki se nanaša na eno koledarsko leto, je analiza stanja vseh treh vidikov trajnosti, pa tudi strokovnosti kmetovanja. Skupaj s priporočili za izboljšanje trajnosti kmetovanja takšna analiza predstavlja zelo dobro osnovo za svetovanje pri trajnostnem razvoju kmetije. Uporabnost sistema SOTKA smo testirali na 20 kmetijah. Čeprav je sistem pokazal zadovoljivo prilagodljivost pri ocenjevanju različno usmerjenih kmetij, so se kljub temu pokazale nekatere omejitve. Naknadno smo že pri prvi verziji sistema SOTKA številne pomanjkljivosti odpravili tako, da smo prilagodili indikatorje potrebam na terenu. Za tiste, ki ostajajo, pa smo navedli možne rešitve, ki jih bo potrebno udejanjiti pri naslednjih izboljšanih verzijah sistema SOTKA.



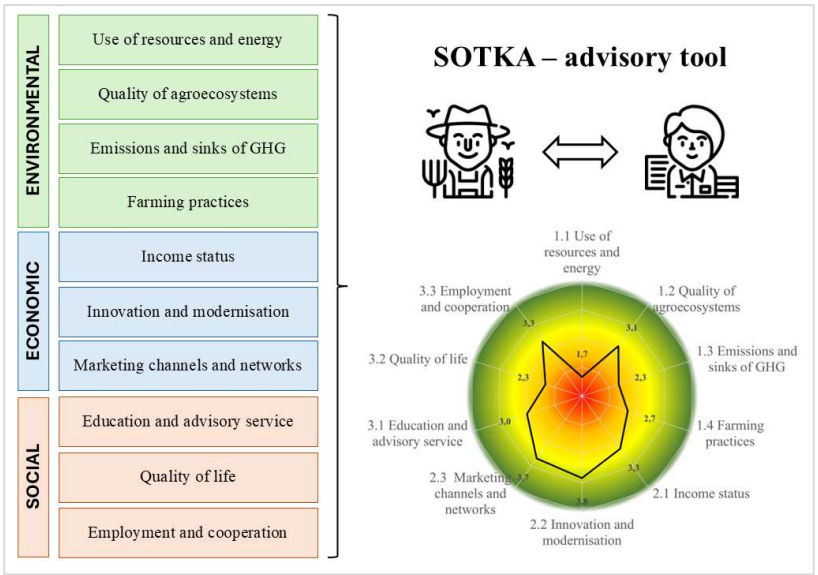
Ključne besede: SOTKA, trajnostno kmetijstvo, indikatorji trajnosti

Zahvala. Delo je nastalo v okviru CRP projekta V4-1813.

[3] Doc. dr., Univerza v Ljubljani, Biotehniška fakulteta, e-pošta: rok.mihelic@bf.uni-lj.si

SOTKA - Slovenian Farm Sustainability Assessment Tool: methodology and testing results

Several farm sustainability assessment tools have been developed around the world, some of which are generic, while others are tailored to specific production and socio-economic conditions. Due to the limited possibilities of using foreign tools for sustainability assessment in Slovenian agriculture, we have developed the SOTKA tool, which is adapted to our conditions and at the same time easy to use. The basis for the development of the SOTKA tool was the generic SAFA system (Sustainability Assessment of Food and Agriculture Systems, FAO). The SOTKA tool consists of 55 indicators, of which 31 are environmental, 14 economic and 10 social. All indicators are precisely defined and are supported by a rating scale with a description of the sustainability score. When assessing the sustainability of a farm, the values of each indicator are entered into the application, which automatically generates diagrams of the farm's sustainability by theme, separately for the environmental, economic and social dimensions. It also displays a polygon with the sustainability scores for all themes, which is the main visual output of the farm's sustainability analysis. The interpretation of the farm's sustainability is based on the average scores of the themes and the scores of the individual indicators. The comprehensive farm sustainability assessment report, which covers a calendar year, is an analysis of the status of all three dimensions of sustainability as well as farming competence. Together with the recommendations for improving the sustainability of farming, such an analysis provides a very good basis for advising on the sustainable development of a farm. We have tested the applicability of SOTKA on 20 farms. Although the system showed a satisfactory flexibility in the assessment of differently oriented farms, some limitations were still recognisable. We have already addressed some of these limitations in the first version of SOTKA by adapting the indicators to the needs of the user, and for the remaining ones we have identified possible solutions to be implemented in the next improved versions of SOTKA.



Keywords: SOTKA, sustainable agriculture, sustainability indicators

Acknowledgement. This work was part of the project CRP V4-1813.

Optimiziranje dognojevanja ozimnih žit s pomočjo preciznega gnojenja

Boštjan FERENČAK[4], Filip VAKAJ, Štefan CIGÜT, Damijan KELC, Peter VINDIŠ, Miran LAKOTA in Lara RESMAN

V okviru projekta EIP Precizno kmetijstvo in digitalizacija je bil na kmetiji Štefana Cigüta izveden poskus preciznega dognojevanja pšenice z dušikom. Poskus se je izvajal na heterogeni njivski površini, velikosti 11,73 ha. Heterogenost površine je bila posledica predhodno izvedene komasacije, zaradi katere je nova površina vključevala več manjših parcel, ki so jih predtem obdelovali različni kmetovalci, pri čemer so bile posejane različne kulture.
Eksperimentalni posevek je predstavljala ozimna pšenica sorte RGT REFORM. Predsetvena obdelava tal je bila izvedena na ohranitveni način brez oranja s krožnim rahljalnikom, setev pa s sejalnico Horsch Pronto. V poskusu sta bili primerjani dve varianti dognojevanja z dušikom vsaka na svoji polovici eksperimentalne površine: (1) fiksni odmerek gnojila in (2) variabilni odmerek dušikovega gnojila. Pri fiksnem dognojevanju je bil odmerek dušika (N) enak povprečnemu odmerku N, uporabljenemu pri variabilnem dognojevanju, s čimer je bila zagotovljena enaka povprečna količina dušikovega gnojila za obe obravnavanji. Dognojevanje je bilo izvedeno v štirih odmerkih z gnojilom KAN 27 %. Priprava map za dognojevanje je potekala s pomočjo programske opreme GeoPard Agriculture, pri čemer so bile mape za vzorčenje ustvarjene na podlagi satelitskih posnetkov. Po razdelitvi površine v cone so bili odvzeti vzorci tal za analizo vsebnosti dušika. Za prvo dognojevanje je bil uporabljen talni nitratni test, za preostala tri dognojevanja pa rastlinski nitratni testi. Na podlagi rezultatov analiz so bile pripravljene mape za dognojevanje, ki so določale specifične odmerke dušika za posamezne dele površine. Žetev pšenice je bila izvedena s kombajnom, opremljenim za kartiranje pridelka, kar je omogočilo izdelavo kart pridelka.
Povprečni pridelek na površini, kjer je bil uporabljen fiksni odmerek gnojila, je znašal 6,749 t/ha, medtem ko je pridelek na površini z variabilnim odmerkom dosegel 6,716 t/ha. Razlika med obema obravnavanjema je bila zanemarljiva (+33 kg/ha v korist fiksnega odmerka), kljub pričakovanju, da bo variabilno dognojevanje omogočilo višji pridelek.
Vzrok za neznačilno razliko med obravnavanji pripisujemo veliki heterogenosti tal, ki je posledica izvedene komasacije v predhodnem letu. Zaradi tega ocenjujemo, da za večji pridelek ni bil omejitveni dejavnik pomanjkanje dušika, ampak nizek pH tal na posameznih delih površine, nadalje različna založenost tal s fosforjem in kalijem ter visoka zbitost tal na posameznih delih njive. Vse te dejavnike je bilo možno opaziti tudi med rastno dobo v obliki slabše rasti posevka na določenih predelih njive. Menimo, da bi bilo potrebno ponoviti poskus na površini, kjer ne bi imeli prej omenjenih omejitvenih dejavnikov, kot so zbitost tal, nizek pH in založenost s fosforjem in kalijem. V takih razmerah bi imel dušik večji vpliv na količino in kvaliteto pridelka.

Ključne besede: pšenica, precizno gnojenje, dušik, mape za gnojenje, satelitski posnetki

[4] Mag., Kmetijsko gozdarska zbornica Slovenije, zavod Murska Sobota, e-pošta: bostjan.ferencak@kgzs-ms.si

Optimizing fertilization of winter cereals through precision fertilization

As part of the EIP project Precision Agriculture and Digitalization, an experiment on precision nitrogen (N) fertilization of wheat was conducted at the Štefan Cigüt farm. The experiment was carried out on a heterogeneous field covering 11.73 ha. The heterogeneity of the field was a consequence of a land consolidation process in the previous year, which resulted in the formation of a new field composed of several smaller parcels previously managed by different farmers and cultivated with various crops.

The experimental crop was winter wheat of the RGT REFORM variety. Pre-sowing soil preparation was performed using a conservation tillage approach without plowing using a disc harrow, sowing was done with a Horsch Pronto seed drill. In the experiment two nitrogen fertilization strategies were compared on two separate plots of the field: (1) a fixed nitrogen application rate and (2) a variable nitrogen application rate adopted to specific field conditions. For the fixed nitrogen application, the N rate was set as a equal to the average N rate applied in the variable-rate treatment, ensuring both treatments received an identical average quantity of nitrogen fertilizer. Fertilization was applied in four doses using KAN 27% fertilizer.

Prescription maps for fertilization were prepared using the GeoPard Agriculture software, based on satellite imagery. Soil samples were collected by zones for nitrogen content analysis. A soil nitrate test was performed for the first fertilization, while plant nitrate tests were used for the subsequent three applications. Based on the analysis results, fertilization maps were created to determine specific nitrogen application rates for different field zones. Wheat harvesting was conducted using a combine harvester equipped with yield mapping technology, enabling the generation of yield maps.

The average yield on the field treated with the fixed nitrogen rate was 6.749 t/ha, while the field treated with the variable nitrogen rate yielded 6.716 t/ha. The difference between the two treatments was negligible (+33 kg/ha in favour of the fixed rate), despite the expectation that variable-rate fertilization would result in higher yields.

The insignificant yield difference is attributed to the high heterogeneity of the field, primarily due to the land consolidation process in the previous year. It was concluded that nitrogen deficiency was not the limiting factor for higher yields. Instead, other factors, such as low soil pH, poor phosphorus and potassium availability, and high soil compaction in specific areas, were more critical. These limiting factors were evident during the growing season as poorer crop growth in certain field sections. It is recommended to repeat the experiment on a more homogeneous field, free from the aforementioned constraints, such as soil compaction, low pH, and insufficient nutrient availability. Under such conditions, nitrogen fertilization is expected to have a more pronounced impact on both yield quantity and quality.

Keywords: wheat, precision fertilization, nitrogen, fertilization maps, satellite imagery

Vezava dušika s podsevki v hmeljišču in ocena pridelka biomase podsevkov v nadpovprečno toplem letu 2024

Barbara ČEH[5], Matej KNAPIČ, Igor ŠANTAVEC, Ana KARNIČNIK KLANČNIK, Bojan ČREMOŽNIK, Monika OSET LUSKAR, Sebastjan RADIŠEK, Jure FERLIN in Boštjan NAGLIČ

S setvijo in zadelavo podsevkov v tla v hmeljiščih lahko pozitivno vplivamo na povečevanje vsebnosti organske snovi v tleh, zaščito tal pred erozijo tako med rastno dobo kot čez zimo, ko so tla sicer gola, izboljšanje biotske raznovrstnosti v tleh in varovanje vodnih virov, saj nase vežejo hranila, ki bi se sicer lahko izgubila iz sistema tla-rastlina. V sklopu poskusov v treh različnih hmeljiščih smo preučevali, katere rastlinske vrste ali njihove mešanice so najprimernejše za uporabo kot podsevki; v kolikšni meri zmanjšajo izgube dušika (N), koliko biomase proizvedejo in kakšen vpliv imajo na biotsko raznovrstnost v tleh. Eksperimentalno delo je temeljilo na bločnih poljskih poskusih s šestimi obravnavanji (pet različnih podsevkov in ena kontrola brez podsevka), izvedenih v treh ponovitvah. Setev podsevkov je potekala med 4. in 8. 7. 2024, hkrati z medvrstno obdelavo tal in zadnjim obsipanjem hmelja. V razmerah leta, za katerega so bile značilne nadpovprečno visoke temperature in nadpovprečna količina padavin, tudi v juliju, se je sudanska trava na vseh treh lokacijah izkazala za najprimernejšo izbiro. Učinkovito je konkurirala plevelom, dosegla največji pridelek biomase in največji odvzem dušika (N). Na lokaciji z bolj odcednimi tlemi sta bili obetavni tudi abesinska gizotija in mešanica bele gorjušice, meliorativne redkve in krmne ogrščice, medtem ko je to mešanico na težjih tleh prerasel plevel. Druge preizkušene različice v razmerah tega leta niso zadostno konkurirale plevelom. Tik pred obiranjem hmelja se vsebnost dostopnega dušika v tleh med posameznimi obravnavanji in kontrolo (plevelna vegetacija) ni bistveno razlikovala, ker je plevel odvzel primerljivo količino dušika kot podsevki, vendar prisotnost plevela do semenitve v hmeljiščih ni priporočljivo zaradi povečanja semenske banke plevelov. V tleh je bilo konec avgusta v medvrstnem prostoru hmeljišča (pod podsevki) med 40 kg/ha (pod sudansko travo) in 48 kg/ha (pri kontroli brez podsevka) mineralnega dušika (nitratna + amonijska oblika) glede na obravnavanje (med obravnavanji sicer ni bilo značilne razlike), glede na globino pa povprečno 45 kg/ha mineralnega N na globini 0–30 cm in 43 kg/ha na globini 30–60 cm. S pomočjo večspektralnega slikanja smo potrdili opazovanja rasti podsevkov, in sicer je bil največji modeliran pridelek biomase in odvzem dušika pri sudanski travi, izstopala je tudi abesinska gizotija. Podsevki imajo tudi ključno vlogo pri podpori talnem ekosistemu, saj zagotavljajo habitate in vire hrane za različen spekter talnih organizmov (vključno z mikroorganizmi), kot so glive, bakterije, arheje, alge, praživali, ter različnimi nevretenčarji. Ti organizmi skupaj tvorijo prehranjevalne verige v tleh. Tipalno vzorčenje tal za biotsko raznovrstnost tik pred obiranjem hmelja je pokazalo, da sta bili najštevilčnejši taksonomski skupini mezofavne tal ne glede na obravnavanja in lokacije pršice (Acarina) in skakači (Collembola). Prve ugotovitve kažejo na nekatere spremembe v mikrobni sestavi tal (bakterije in glive) v času aktivne rasti podsevkov, kar nakazuje njihov vpliv na talne ekosisteme, zato se bomo v prihodnje tej temi podrobneje posvetili, poleg tega pa je potrebno poskuse ponoviti še v več letih, ko bodo vremenske razmere drugačne.

Ključne besede: podsevki, mešanice kot podsevki, sudanska trava, abesinska gizotija, zajem dušika, mineralni dušik v tleh, večspektralno slikanje, biotska raznovrstnost v tleh

[5] Dr., Inštitut za hmeljarstvo in pivovarstvo Slovenije, e-pošta: barbara.ceh@ihps.si

Nitrogen uptake by catch crops in hop fields and their biomass production in an exceptionally warm year 2024

By sowing and incorporating catch crops into the soil in hop fields, we can positively impact the increase of organic matter content in the soil, protect the soil from erosion both during the growing season and over winter when the soil would otherwise remain bare, enhance soil biodiversity, and safeguard water resources by capturing nutrients that might otherwise be lost from the soil-plant system. In a series of field experiments conducted at three different hop fields, we investigated which plant species or their mixtures are most suitable as catch crops in hop cultivation. Our focus was on the extent to which they reduce nitrogen (N) losses, the amount of biomass they produce, and their impact on soil biodiversity. The experimental work was based on block field trials with six treatments (five different catch crops and control without catch crops), conducted in three replicates. Catch crop sowing was carried out between July 4 and July 8, 2024, concurrently with inter-row soil cultivation and the final hilling of hop. In the conditions of 2024, characterized by above-average high temperatures and above-average rainfall, including in July, Sudan grass proved to be the most suitable choice across all three locations. It effectively competed with weeds, achieved the highest biomass yield, and exhibited the greatest nitrogen (N) uptake.

At the location with more well-drained soils, ramtil (*Guizotia abyssinica* (L. f.) Cass.) and the mixture of white mustard, tillage radish, and forage rape also showed promise. However, on heavier soils, this mixture was overtaken by weeds. Other tested variants were not sufficiently competitive against weeds under the conditions of this year.

Just before the hop harvest, the available nitrogen content in the soil did not significantly differ among treatments and the control (where weeds had grown), indicating that weeds captured a comparable amount of nitrogen to the catch crops. However, allowing weeds to grow in hop fields is not advisable due to the increase in the weed seed bank.

At end August, 2024, the mineral nitrogen content (nitrate + ammonium forms) in the inter-row space of the hop field (under the catch crops) ranged from 40 kg/ha (under Sudan grass) to 48 kg/ha (in the control without catch crops), depending on the treatment (no significant differences were observed among treatments). By soil depth, the average mineral nitrogen content was 45 kg/ha at 0–30 cm and 43 kg/ha at 30–60 cm depth at that time.

Using multispectral imaging, we confirmed observations of catch crop growth, with the highest modelled biomass yield and nitrogen uptake observed in Sudan grass, while ramtil also stood out.

Catch crops play a crucial role in supporting the soil ecosystem by providing habitats and food resources for a diverse range of soil organisms, including microorganisms such as fungi, bacteria, archaea, algae, and protozoa, as well as various invertebrates. Together, these organisms form the soil food web. Soil sampling for biodiversity, conducted just before the hop harvest, revealed that the most abundant taxonomic groups of soil mesofauna, regardless of treatments and locations, were mites (Acarina) and springtails (Collembola).

The initial findings indicate certain changes in the microbial composition of the soil (bacteria and fungi) during the active growth period of catch crops, suggesting their impact on soil ecosystems. This topic will be explored in greater detail in future studies. Additionally, the experiments need to be repeated over multiple years with varying weather conditions.

Keywords: cover crops, mixtures as cover crops, Sudan grass, ramtil (*Guizotia abyssinica* (L. f.) Cass.), nitrogen uptake, soil mineral nitrogen, multispectral imaging, soil biodiversity

Optimizacija biološke razgradnje gnojevke za zmanjšanje izgub dušika v kmetijstvu

Kristina ZORKO[6], Boštjan KRISTAN, Martina DOBAJ GOMBOC, Anja MEŽAN in Ožbej Ivan ZORKO

S projektom Optimizacije biološke razgradnje gnojevke z uporabo produktov, ki vsebujejo aerobne, anaerobne in anoksične mikroorganizme in njena raba v kmetijstvu želimo zmanjšati izgube dušika in emisije amonijaka ter izboljšati vsebnost hranil v živinskih gnojilih. V projektu izvajamo praktični preizkus na šestih kmetijskih gospodarstvih, ki se ukvarjajo z živinorejo (krave molznice, goveji pitanci, plemenske svinje). Za obdelavo gnojevke se uporabljajo proizvodi italijanskega proizvajalca Eurovix S.p.A., ki vsebujejo mešanice različnih mikroorganizmov, encimov in drugih koristnih sestavin. Na ta način koristno mikrobno floro dodamo ter obenem spodbudimo aktivnost avtohtone mikrobne združbe kar optimizira postopek biološke razgradnje gnojevke. Doziranja se med kmetijami razlikujejo, saj so odvisna od živalske vrste (govedo/prašiči), števila živali ter intenzivnosti prireje. Kombinacijo praškastih proizvodov Micropan Normal in Micropan Biogas sodelujoča kmetijska gospodarstva s pomočjo puhala na rešetke nanašajo 2x tedensko. Tablete Micropan Biogas (govedo) ali Micropan Liquam flow (prašiči) se razporedijo po celotni gnojni jami po vsaki izpraznitvi jame. Euroactiv Agro se dodaja tik pred razvozom gnojevke, neposredno v cisterno.
Meritve delcev amonijaka opravljamo z merilnimi napravami Dräger Pac 8000. Z uporabo proizvodov so se znatno zmanjšale emisije amonijaka v hlevih. V nekaterih primerih uporabe proizvodov za obdelavo gnojevke se je koncentracija delcev amonijaka v zraku v hlevih ponekod zmanjšala do ničelne vrednosti, kar ima pozitiven vpliv na dobrobit živali. Gospodarji na sodelujočih kmetijskih gospodarstvih so opazili tudi druge pozitivne spremembe: zmanjšano število muh na kmetijah, učinkovitejše obvladovanje penjenja ter zmanjšanje neprijetnih vonjav na dvorišču kmetije in pri razvozu gnojevke. Uporaba proizvodov je olajšala mešanje gnojevke, saj preprečuje pretirano zgoščevanje in nastajanje skorje. Proučevali smo še vpliv načina nanosa gnojevke (z vlečenimi cevmi in standardni raztros z razpršilno ploščo) na emisije amonijaka. Rezultati kažejo, da je število delcev amonijaka pri raztrosu z vlečenimi cevmi opazno manjše, kar potrjujejo tudi dosedanje raziskave. Dosedanje ugotovitve projekta podpirajo upravičenost ukrepov, ki zagotavljajo trajnejšo rabo gnojevke in odpirajo nove možnosti za zmanjševanje negativnih vplivov kmetijstva na okolje.

Ključne besede: gnojevka, emisije amonijaka, dušik, dobrobit živali, gnojenje

Zahvala. Projekt EIP (Evropsko inovativno partnerstvo) z naslovom »Optimizacija biološke razgradnje gnojevke (s produkti, ki vsebujejo aerobne, anaerobne in anoksične mikroorganizme) za zmanjšanje izgub dušika in njena raba v kmetijstvu«, se izvaja v okviru ukrepa M16: Sodelovanje iz programa razvoja podeželja, podukrep 16.2: Razvoj novih proizvodov, praks, procesov in tehnologij iz PRP 2014- 2020.

[6] Mag. varstvoslovja, JPZ Janez Zorko s.p., e-pošta: kristina.zorko89@gmail.com

Optimization of biological slurry degradation to reduce nitrogen losses in agriculture

The EIP project titled Optimization of Biological Slurry Degradation Using Products Containing Aerobic, Anaerobic, and Anoxic Microorganisms and Its Use in Agriculture aims to reduce nitrogen losses, decrease ammonia emissions, and improve the nutrient content of livestock manure. The project involves a practical trial on six livestock farms (dairy cows, beef cattle, and breeding sows). Products from the Italian manufacturer Eurovix S.p.A. are used for slurry treatment, containing mixtures of various microorganisms, enzymes, and other beneficial components. These products introduce beneficial microbial flora and stimulate the activity of the native microbial community, optimizing the biological degradation process of the slurry. Dosages vary between farms, depending on the type of livestock (cattle/pigs), the number of animals, and the intensity of production.

A combination of powdered products, Micropan Normal and Micropan Biogas, is applied twice a week to slatted floors using blowers. Micropan Biogas tablets (for cattle) or Micropan Liquam Flow tablets (for pigs) are distributed throughout the slurry pit after each emptying. Euroactiv Agro is added directly to the slurry tank just before spreading.

Ammonia particle measurements are conducted using Dräger Pac 8000 devices. The use of these products has significantly reduced ammonia emissions in barns, with ammonia concentrations in some cases dropping to zero, positively impacting animal welfare. Farmers have also observed other positive effects: reduced fly populations, better control of slurry foaming, and fewer unpleasant odors on farms and during spreading. These products have also made slurry mixing easier by preventing excessive thickening and crust formation.

The project further examines the impact of slurry application methods, comparing trailing hoses and standard broadcast spreading with a splash plate. Results show that ammonia particle counts are significantly lower with trailing hoses, consistent with previous research. These findings highlight the importance of measures for sustainable slurry management and open new possibilities for reducing the negative environmental impacts of agriculture.

Keywords: slurry, ammonia emissions, nitrogen, animal welfare, fertilization.

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Monitoring biodiverzitete v slovenski kmetijski krajini in predlogi za nadgradnjo

Irena BERTONCELJ[7]

Obstoj približno četrtine habitatnih tipov, uvrščenih v prilogo I EU Direktive o habitatih, je odvisen od ekstenzivnih kmetijskih praks. Intenzifikacija kmetijstva je v poročilu Evropske komisije o stanju narave v EU kmetijstvo navedena kot najpogostejša grožnja za te habitatne tipe in na njih vezane vrste. Skupna kmetijska politika nameni del sredstev za naravovarstvene kmetijsko-okoljsko-podnebne (KOPOP) ukrepe, s katerimi naj bi zmanjšali negativne vplive kmetijstva na biodiverziteto. Za spremljanje vplivov kmetijstva in učinkov KOPOP ukrepov pa je nujna vzpostavitev monitoringa biodiverzitete, ki omogoča ocenjevanje sprememb v času in prostoru. Slovenska kmetijska krajina je vključena v pet mednarodnih monitoring shem, ki spremljajo biodiverziteto: European Monitoring of Biodiversity in Agricultural Landscapes (EMBAL), Land Use and Coverage Area Frame Survey (LUCAS), EU Butterfly Monitoring Scheme (eBMS), Pollinator species monitoring sheme (EUPoMS), EU common Bird monitoring scheme (PECBMS). Pregled obstoječih monitoring shem v Sloveniji je pokazal, da se nacionalne monitoring sheme biodiverzitete osredotočajo večinoma na redke in ogrožene vrste, nimamo pa monitoringa pogostih in splošno razširjenih vrst. Najslabše so z monitoringom zajete rastline in habitatni tipi, za katere se nesistematično in neredno izvaja monitoring v Natura 2000 območjih samo za izbranih 8 % rastlinskih vrst. Rednega spremljanja kvantitativnih in kvalitativnih kazalnikov ohranitvenega stanja habitatnih tipov ne more nadomestiti kakovosten in dostopen sloj rabe zemljišč. Trenutno tudi nimamo vzpostavljenega nacionalnega monitoringa talnih živali, kot so deževniki, skakači in pršice, ki so za kmete zanimive taksonomske skupine. Prav tako še nimamo vzpostavljenega monitoringa učinkovitosti naravovarstvenih KOPOP ukrepov Skupne kmetijske politike, s katerim bi lahko usmerjali njihovo pripravo v prihodnosti.
S prostorsko razširitvijo nekaterih mednarodnih shem, kot je eBMS za metulje, bi lahko nacionalni monitoring nadgradili s spremljanjem splošno razširjenih vrst. Shemi EMBAL in LUCAS že potekata na relativno velikem številu naključno izbranih točk in kvadrantov, vendar beležita splošne kazalnike, kot so raba tal, število cvetočih rastlin in pokrovnosti indikatorskih rastlinskih taksonov. Monitoring bi lahko na EMBAL kvadrantih dopolnili s popisi rastlinskih in živalskih vrst in tako zagotovili beleženje trendov splošno razširjenih vrst v slovenski kmetijski krajini.

Ključne besede: kazalniki biodiverzitete, mednarodne monitoring sheme, skupna kmetijska politika, kmetijsko-okoljsko-podnebni ukrepi

Orhideje so kazalniki ekstenzivnih kmetijskih praks.
Orchids are indicators of extensive agricultural practices.

[7] Dr., Kmetijski inštitut Slovenije, e-pošta: irena.bertoncelj@kis.si

Biodiversity monitoring in agricultural landscapes of Slovenia and proposals for its upgrading

The existence of about a quarter of the habitat types of European importance, listed in Annex I of the EU Habitats Directive depends on extensive agricultural practices. Due to intensification, the European Commission's report on the state of nature in the EU lists agriculture as the most common threat to these habitat types and their associated species. To reduce the negative impacts of agriculture on biodiversity, the Common Agricultural Policy allocates part of the funds for agri-environment-climate schemes (AEC). In order to monitor the effects of agriculture and AEC schemes, it is necessary to establish biodiversity monitoring, which enables the assessment of changes in time and space.

Currently five international monitoring schemes of biodiversity also include Slovenian agricultural landscapes: European Monitoring of Biodiversity in Agricultural Landscapes (EMBAL), Land Use and Coverage Area Frame Survey (LUCAS), EU Butterfly Monitoring Scheme (eBMS), Pollinator species monitoring sheme (EUPoMS), EU common Bird monitoring scheme (PECBMS). The review of existing monitoring schemes in Slovenia showed that the national biodiversity monitoring schemes focus mostly on rare and endangered species, but we do not have monitoring of common and widespread species. Plants and habitat types are the most neglected as only selected 8% of plant species are non-systematically and not regularly monitored within Natura 2000 sites. Regular monitoring of quantitative and qualitative indicators of the conservation status of habitat types cannot be replaced by a high-quality and accessible layer of land use. At the moment, we also do not have national monitoring of soil animals, which have been recognized as a taxonomic group of interest to farmers. We also do not yet have an established monitoring of the effectiveness of the nature conservation AEC measures of the Common Agricultural Policy, which could be used to guide their development in the future.

By adding more sampling sites to some international schemes, such as the eBMS for butterflies, national monitoring could be expanded to include common species. The EMBAL and LUCAS schemes already run on a relatively large number of randomly selected points and quadrants, but only record general indicators such as land use, number of flowering plants and cover of indicator plant taxa. This could be upgraded by monitoring of plants and animals in EMBAL quadrants and thus ensure the recording of trends of widespread species in the Slovenian agricultural landscape.

Keywords: biodiversity indicators, international monitoring schemes, Common agricultural policy, agri-environment schemes

V Sloveniji nimamo vzpostavljenega rednega sistematičnega monitoringa rastlin.
Currently there is no regular and systematic monitoring of plants in Slovenia.

Tradicionalno upravljanje travnikov za ohranjanje biodiverzitete

Jože BAVCON[8] in Blanka RAVNJAK

Travniki, nekdaj nepogrešljivi pisani zakladi krajine in ključna dobrina kmečkega človeka, so danes zelo ogroženi. Prezgodnja košnja, siliranje in baliranje sena siromašijo rastlinsko vrstno pestrost travnikov, ki pa so, sicer izmed vseh habitatnih tipov v našem okolju biodiverzitetno, najbolj pestri. Prav tako se izgubljata tradicionalno znanje, ki je omogočalo trajnostno rabo prostora, ki je povezovalo človeka z naravo.
Ročna košnja je bila veliko stoletij edini način pridobivanja krme za živino. Posebej v hribovitih delih Slovenije, kjer so ljudje skozi stoletja krčili gozd za pridobitev novih senožeti - strmih travnikov. Le-te pa so ohranjali z redno košnjo in krčenjem gozdnega roba. Na nekaj let so gozdni rob posekali, pri čemer je posekani material služil za kurjavo. Ko je ročna košnja zamrla in se je prešlo na strojno pridelavo, je večina teh strmih predelov zaradi nedostopnosti strojni košnji ostala nepokošena, saj so bila ta zemljišča prestrma. Zato so se z opuščanjem ročne košnje začela zaraščati. Strojna košnja je prišla v poštev le na položnejših zemljiščih. Vendar je prav tako tudi mnoge od teh doletela enaka usoda opuščanja košnje in nato zaraščanja. Nekatere pa so se spremenile v intenzivna kmetijska zemljišča za pridelavo krme.
Z množičnejšo uporabo mineralnih gnojil so se travniki, ki so omogočali strojno košnjo, relativno hitro spremenile v večkosne travnike. Še večja sprememba se je zgodila ob koncu devetdesetih let, ko so tudi v Sloveniji začeli krmo balirati v plastične bale, kar je preprečilo obnovo naravne semenske banke v tleh. Z nekaj leti so vsi travniki z intenzivno rabo postali le še zelene valujoče planjave, kjer so prevladovale trave, za razliko od ekstenzivnih travnikov, kjer je bilo poleg trav prisotnih še mnogo trajnih ali enoletnih zeli. Z novimi metodami upravljanja okolja žal ne znamo več ohranjati kulturne krajine, ki jo je človek vzdrževal skozi zgodovino. S tem pa zgubljamo tudi biodiverziteto, tako rastlinsko kot živalsko, in narave ne razumemo več celostno. Prav ohranjane pisanih travnikov je proces, ki zahteva celosten pristop in zato moramo poznati tradicionalne metode, da bomo lahko biodiverziteto vzdrževali tudi na sodoben način. S pravilnim upravljanjem travnika so se na suhem travniku za Savo povečale populacije nekaterih zavarovanih in redkih vrst, kot so *Gladiolus illyricus* Koch, *Lilium bulbiferum* L., *Anthericum ramosum* L. in *Chamaecytisus purpureus* Scop.. Med njimi so se povečale tudi populacije petnajstih vrst kukavičevk (npr. *Oprhys holosericea* (Burm. F) Greuter). Celokupno število vrst pa je z začetnih 48 naraslo na 164 vrst.

Ključne besede: enokosni, dvokosni travniki, tradicionalna raba, varovanje rastlinskih vrst, naravne semenske banke, *in-situ* varovanje

[8] Dr., Botanični vrt Univerze v Ljubljani, Biotehniška Fakulteta, e-naslov: Jože Bavcon joze.bavcon@guest.arnes.si

Traditional grassland management for biodiversity conservation

Meadows, once indispensable colourful treasures of the landscape and a key asset for farmers, are now very much under threat. Premature mowing, silage and hay baling are impoverishing the plant diversity of meadows, which are the most diverse of all habitat types in our environment in terms of biodiversity. Traditional knowledge that enabled sustainable use of space and connected people with nature is also being lost.

For many centuries, hand mowing was the only way to obtain fodder for livestock. Especially in the hilly parts of Slovenia, people have been clearing forests for centuries to obtain new steep meadows. These were maintained by regular mowing and clearing the forest edge. For a few years, the forest edge was cut down and the cut material was then used for firewood. When hand mowing was replaced by cutting machines, most of these steep meadows remained unmowed due to the inaccessibility of machines. These areas were too steep for mechanical mowing. Therefore, these areas began to overgrow with the abandonment of manual mowing. Mechanical mowing was only considered on flatter areas. However, many of these also suffered the same fate of abandonment of mowing and then overgrowth. Some of them were transformed into intensive areas for fodder production.

With the widespread use of mineral fertilizers, areas suitable for mechanical mowing were relatively quickly transformed into areas that were mowed several times a year. An even greater change occurred at the end of the 1990s, when Slovenia also began baling fodder into plastic bales, which prevented the renewal of the natural seed bank in the soil. Within a few years, all intensively cultivated areas became nothing more than green plains dominated by grasses, unlike previous areas where, in addition to grasses, many perennial or annual herbaceous plant species were present. Unfortunately, with new methods of environmental management, we are no longer able to preserve the cultural landscape that man has maintained throughout history. This also means we are losing biodiversity, both plant and animal, and we no longer understand nature holistically. Maintaining colourful meadows is a process that requires a holistic approach, and therefore we need to know traditional methods so that we can maintain biodiversity in a modern way. With proper meadow management, populations of some protected and rare species such as *Gladiolus illyricus* Koch, *Lilium bulbiferum* L., *Anthericum ramosum* L. and *Chamaecytisus purpureus* Scop. have increased in the dry meadow behind the Sava. Among them, populations of fifteen species of Orchidaceae family (e.g. *Oprhys holosericea* (Burm. F) Greuter) have also increased. The total number of species has increased from the initial 48 to 164 species.

Keywords: single-crop, double-crop meadows, traditional management, plant conservation, natural seed banks, *in-situ* conservation

Cvetoči travniki v Čičariji

Flowering meadows at Čičarija (Foto. J. Bavcon)

Od mikrobov do N_2O emisij

Anton GOVEDNIK [9], Klemen ELER, Rok MIHELIČ in Marjetka SUHADOLC

Znano je, da lahko z manjšo intenzivnostjo obdelave tal povečamo vsebnost organskega ogljika (SOC) v zgornjem sloju tal, kar pa lahko hkrati vodi do večjih emisij didušikovega oksida (N_2O) mikrobiološkega izvora. V naši študiji smo analizirali vpliv dveh različnih načinov obdelave tal [brez obdelave tal (NT) v primerjavi s konvencionalno obdelavo tal s plugom (CT)] v kombinaciji z različnimi načini gnojenja [mineralnim (MIN), kompostom (ORG) in negnojeno kontrolo (CON)], ki sta trajala dve desetletji, na fizikalne, kemične in biološke lastnosti tal ter emisije N_2O. Prvo vzorčenje tal smo izvedli do globine 60 cm, nato pa smo sezonsko vzorčili pline in zgornji sloj tal (0–10 cm). V zgornjem sloju tal (0–10 cm) smo ugotovili večjo vsebnost SOC v NT (3,2 %) kot v CT (2,3 %). Gnojenje je istočasno vplivalo na SOC do globine 20 cm z večjimi vsebnostmi pri gnojenju ORG kot pri ostalih. Povprečne vrednosti SOC v zgornjih 20 cm tal so bile od 2,8 % pri gnojenju ORG do 2,2 % pri negnojeni kontroli. Najvišje povprečne vsebnosti SOC v zgornjem sloju tal (0–10 cm) smo izmerili v kombinaciji obravnavanj NT in ORG z vsebnostjo SOC 3,8%. Vzorec porazdelitve SOC se je ujemal z gradientom mikrobne biomase in številčnosti splošne mikrobne združbe (16S in ITS) ter N-funkcionalnih genov (qPCR). Največje sezonske kumulativne emisije N_2O smo izmerili pri gnojenju z mineralnimi gnojili (MIN), sledili sta gnojenji ORG in CON. Vzorec porazdelitve kumulativnih emisij pozitivno sovpada z velikostjo deleža amonij oksidirajočih bakterij (AOB/16S), ki se je pokazal kot ena glavnih pojasnjevalnih spremenljivk multiple regresije. Večji genetski potencial za emisije N_2O, izražen kot večje razmerje v genih kodirajočih nitrit reduktaz (*nirS* in *nirK*) in reduktaz N_2O (*nosZI* in *nosZII*), predstavljen kot (*nirK*+*nirS*)/(*nosZI*+*nosZII*), smo ugotovili pri NT kot pri CT, vendar se ni odrazil v večjih emisijah. Manjše kumulativne emisije od pričakovanih v NT-ORG lahko pripišemo povečanemu potencialu ponora N_2O, ki je pozitivno soodvisen z deležem *nosZII* v talnem metagenomu. Naši rezultati kažejo, da je organsko gnojenje v kombinaciji z NT obetavna kombinacija za zmanjševanje emisij N_2O, vendar je pred vključitvijo teh praks v priporočila za prakso potrebno preučiti tudi njun vpliv na velikost pridelka.

Ključne besede: ohranitveno kmetijstvo, direktna setev, kompost, mikrobna združba N-cikla, N_2O, potencialna denitrifikacija, 16S združba, *nosZ* združba

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[9] Univerza v Ljubljani, Biotehniška fakulteta, e-pošta: anton.govednik@bf.uni-lj.si

From microbes to N_2O emissions

Reduced tillage intensity is known to increase soil organic carbon (SOC) in the topsoil but can also lead to increased microbially derived nitrous oxide (N_2O) emissions. In this study, we evaluated the effects of two tillage systems [no-till (NT) vs. conventional plough tillage (CT)] in combination with different fertilisation treatments [mineral (MIN), compost (ORG), and unfertilised control (CON)] on soil physical, chemical and biological properties, as well as N_2O emissions, after more than two decades. First soil sampling was conducted down to 60 cm, followed by seasonal gas and topsoil (0-10 cm) sampling. In the upper 0-10 cm of soil, a higher SOC content in NT than in CT was found, namely 3.2% and 2.3% in NT and CT, respectively. Meanwhile, fertilization affected SOC up to 20 cm depth with higher contents in ORG fertilization than in the others. The mean SOC values in the top 20 cm of soil ranged from 2.8% in ORG to 2.2% in CON. The highest average SOC contents in the top 0-10 cm were measured in the combination of NT and ORG treatments with a SOC content of 3.8%. This pattern correlated with the gradient of microbial biomass and total microbial community abundance (16S and ITS) including N-functional gene abundances (qPCR). The highest seasonal cumulative N_2O emissions were measured in MIN fertilization, followed by ORG and CON, coinciding with proportion of ammonia oxidising bacteria in bacterial community (AOB/16S) as one of the main explanatory variables of multiple regression. A higher genetic potential for N_2O emissions expressed as an increased ratio between nitrite reductases (*nirS* and *nirK*) and N_2O reductases (*nosZI* and *nosZII*), presented as (*nirK*+*nirS*)/(*nosZI*+*nosZII*), was observed under NT than CT, although this potential was not realized in the form of increased emissions. Lower than expected cumulative emissions in NT-ORG were explained by an increased N_2O sink potential, which positively correlated with proportion of *nosZII* in the metagenome. Our results suggest combining organic fertilisation with NT as a promising approach for mitigating N_2O emissions; however, addressing the yield gap is necessary before incorporating those practices into recommendations for farmers.

Keywords: conservation agriculture, no-till, compost, N-cycling microbial community, N_2O, potential denitrification, 16S community, *nosZ* community

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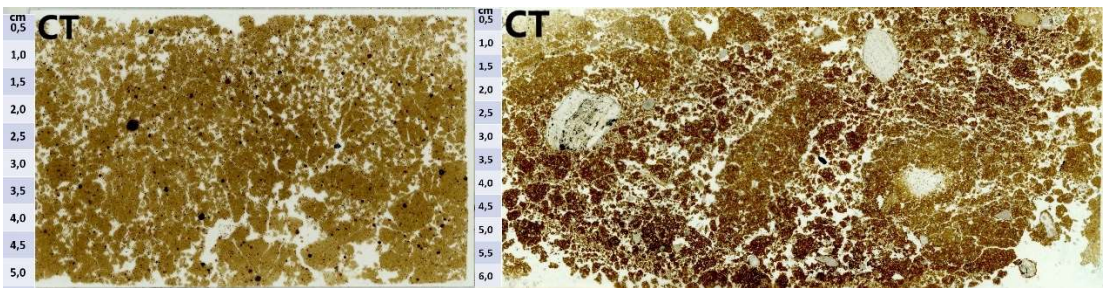
Mikromorfološki vpogled v različno obdelana tla

Sara MAVSAR[10], Helena GRČMAN, Agni PRIJATELJ in Rok MIHELIČ

Nastajanje agregatov in izboljšanje strukture tal je mogoče doseči z različnimi praksami upravljanja tal, ki zmanjšujejo motnje kmetijskega ekosistema, izboljšajo rodovitnost tal, povečajo sekvestracijo ogljika v tla, povečajo pokritost tal in zmanjšajo stopnjo razgradnje organskega ogljika v tleh (SOC). Ena od takšnih praks upravljanja tal je obdelava. Pri intenzivni obdelavi imajo tla večjo skupno poroznost kot tla, obdelana z zmanjšano obdelavo. V prvem primeru gre za večja sezonska nihanja skupne poroznosti, pri zmanjšani obdelavi pa je večji delež večjih por, kar je ugodno za vodni režim tal in rast korenin. Zmanjšana obdelava tal je primernejša za ohranjanje želenih pogojev tal in preprečevanje degradacije strukture tal kot intenzivna obdelava tal.
Namen naše raziskave je bil oceniti učinke dveh različnih intenzivnosti obdelave tal (CT, konvencionalna obdelava tal; NT, no-till) na strukturo tal in organsko snov z mikromorfološko analizo. Mikromorfologija je pedološka metoda, ki omogoča z optičnim mikroskopiranjem *in situ* opazovanje mikrostrukture tal, prostorskih razmerij med porami in talnimi agregati ter prostorske razporeditve različnih tipov organske snovi v tleh. Omenjene lastnosti tal analiziramo v talnih zbruskih, t. j. v orientiranih neporušenih vzorcih tal, ki so bili odvzeti iz talnih profilov in ki se, po predhodnem odstranjevanju vode in impregnaciji z umetnimi smolami, nalepijo na objektna stekelca ter postopoma zbrusijo do debeline 0,03 mm.
Mikromorfološko vzorčenje je bilo izvedeno na dveh poskusnih lokacijah v Moškanjcih, ki se razlikujeta po teksturi tal (»Mamino«, 20–24 % gline in »Kumrovo«, 51–55 % gline). Spomladi leta 2022, po žetvi koruze v letu 2021, smo na obeh lokacijah izkopali profile na ploskvah CT in NT ter iz njih odvzeli neporušene vzorce s pomočjo kovinskih U-profilov ali mavčnih trakov. Vzorci so bili odvzeti na globinah 0–15, 8–23, 18-33 in 30–45 cm in izdelani v talne zbruske v laboratorijih v Franciji in Belgiji. Zbruske smo pregledali pod stereomikroskopom in optičnim mikroskopom s polarizirano svetlobo pri 8–200 kratnih povečavah. Analiza zbruskov kaže, da NT (i) poveča aktivnost organizmov v tleh, predvsem v zgornjih centimetrih, (ii) poveča agregacijo – nastanek večjih strukturnih agregatov, saj sistem obdelave tal agregatov ne zdrobi na manjše, kot je to značilno za oranje in (iii) poveča količino rastlinskih ostankov pod površjem (0–2 cm).

Ključne besede: struktura tal, strukturni agregati, organska snov, obdelava, no-till



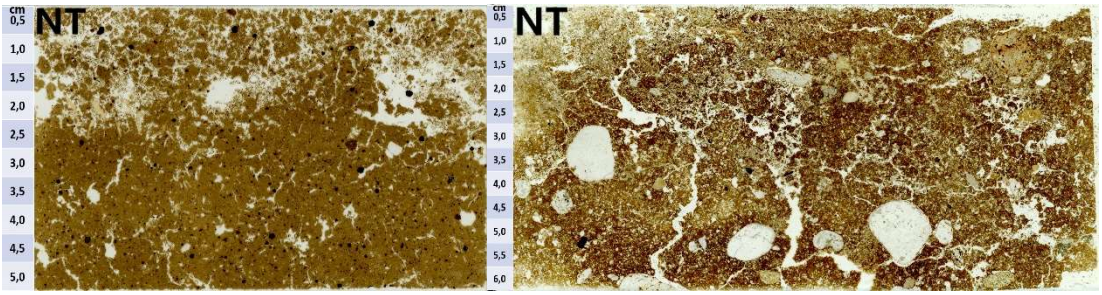
Horizontalni zbrusek na lokaciji "Kumrovo" (0–5 cm) levo in "Mamino" (0–6 cm) desno (na CT obravnavanju).
Horizontal thin section at site "Kumrovo" (0-5 cm) on left and at "Mamino" (0-6 cm) on the right (on CT treatment).

[10] Mag. inž. agr., Biotehniška fakulteta, Oddelek za agronomijo, e-pošta: sara.mavsar@bf.uni-lj.si

Micromorphological perspective on different soil tillage systems

The aggregate formation and the improvement of soil structure can be achieved through various soil management practices that reduce agro-ecosystem disturbance, improve soil fertility, increase the C sequestration into the soil, increase plant cover, and decrease soil organic carbon (SOC) decomposition rates. One such management practice is tillage. Soils subjected to intensive tillage generally have a higher total porosity than soils subjected to reduced tillage. In the former case, there is greater seasonal variation in total porosity, while reduced tillage tends to result in a higher proportion of transmission pores, which benefits both the water regime and root growth. Reduced tillage is better suited to maintain the desired soil conditions and prevent soil structure degradation compared to intensive tillage.
The aim of our study was to evaluate the effects of two different tillage intensities (CT, conventional tillage; NT, no-till) on soil structure and organic matter using micromorphological analysis. Micromorphology is a soil science technique that allows the observation of soil microstructure, the spatial relationships between pores and soil aggregates, and the spatial distribution of various types of organic matter in situ using optical microscopy. These soil properties are analysed in thin sections prepared from oriented, undisturbed soil samples taken from soil profiles. The samples are oven dried and impregnated with synthetic resins, with the impregnated slices mounted on glass slides and gradually ground to a thickness of 0.03 mm.
Micromorphological sampling was carried out at two experimental sites in Moškanjci (Slovenia) with different soil texture ("Mamino", 20-24% clay; "Kumrovo", 51-55% clay). In the spring of 2022, after the 2021 maize harvest, we excavated profiles on the CT and NT plots at both sites and extracted undisturbed block samples using metal U-profiles or plaster of Paris dressings. Samples were taken at depths of 0-15, 8-23, 18-33 and 30-45 cm, and processed into thin sections in laboratories in France and Belgium. The thin sections were examined under a stereomicroscope and an optical microscope with polarized light at 8x to 200x magnification. Analysis of the thin sections shows that NT (i) increases the activity of soil organisms, especially in the top centimetres; (ii) promotes aggregation, resulting in the formation of larger structural aggregates, as the NT system prevents the fragmentation of aggregates into smaller ones, which is typical of ploughing, and (iii) increases the amount of plant residue just below the surface (0-2 cm).

Keywords: soil structure, aggregates, organic matter, tillage, no-till



Horizontalni zbrusek na lokaciji "Kumrovo" (0-5 cm) levo in "Mamino" (0-6 cm) desno (na NT obravnavanju).
Horizontal thin section at site "Kumrovo" (0-5 cm) on left and at "Mamino" (0-6 cm) on right (on NT treatment).

Grahor kot potencialna stročnica za razširitev kolobarja na srbskih in slovenskih njivah

Aleksandra ILIĆ[11], Nevena NAGL, Ana UHLARIK, Mirjana VASIĆ, Barbara PIPAN, Vladimir MEGLIČ in Lovro SINKOVIČ

Čeprav izvira navadni grahor (*Lathyrus sativus* L.) iz Sredozemlja, velja Balkanski polotok za njegovo vstopno pot v Evropo. Grahor je bil v preteklosti razširjena in znana poljščina v kmetijstvu zahodnega Balkana, tudi Srbije in Slovenije. Danes se v primerjavi z drugimi stročnicami prideluje le na majhnih površinah in velja za zapostavljeno vrsto. Zaradi njegovih pozitivnih lastnosti, kot so visoka vsebnost beljakovin, odpornost na sušo in poplave, smo izvedli poskuse ponovne uvedbe grahorja v srbski in slovenski kmetijski sistem. Sprva sta bili oblikovani zbirki grahorja IFVCNS (Inštitut za ratarstvo in povrtarstvo, Novi Sad) in KIS (Kmetijski inštitut Slovenije) ter uporabljeni za fenotipsko in agronomsko vrednotenje v okviru mednarodno pobude "EUGrainLeg". Gonilna sila teh aktivnosti je bila nastajajoča potreba po diverzifikaciji kmetijskih sistemov in njihovi večji trajnosti z vključitvijo nadomestnih ali dodatnih podnebnim spremembam prilagojenih stročnic, kot je grahor. To delo je bilo kasneje razširjeno v okviru dveh bilateralnih projektov v povezavi z genetsko variabilnostjo in vrednotenjem prehranskih lastnosti, vključno z antinutritivnimi spojinami v grahorju, kot so inhibitorji proteaz.

Poleg pregleda dela, opravljenega v poskusu raziskovanja in popularizacije uporabe grahorja na Zahodnem Balkanu, ta raziskava predstavlja rezultate poljskih poskusov, ki sta bila opravljena v Srbiji in Sloveniji med rastno sezono 2019 na devetih akcesijah grahorja (osem akcesij iz srbske in ena iz slovenske genske banke). Ocenjevali smo osnovne lastnosti (višina rastlin, število dni do 50 % cvetenja in zrelosti, število strokov na rastlino, število semen na strok, število semen na rastlino, masa 1000 semen), ki vplivajo na velikost pridelka. Na splošno so se vse akcesije grahorja v teh dveh okoljih pokazale kot zadovoljive, z manjšimi razlikami. Rastna doba je bila enaka (87 dni do zrelosti) z nekoliko krajšim časom cvetenja v Sloveniji. Največja razlika je bila pri številu strokov na rastlino (28,1 oz. 9,2 strokov na rastlino v Sloveniji in Srbiji), medtem ko sta bila število semen na strok in pridelek semena na rastlino podobna (1,8 in 2,4 semen na strok; 17,3 in 16,1 semen na rastlino v Srbiji in Slovenji). Poleg tega je bilo na srbskih akcesijah opravljeno že prvo vrednotenje aktivnosti inhibitorjev kimotripsina (CI), medtem ko je to potrebno na slovenski dednini še izmeriti. Aktivnost CI je bila v razponu od 10,3 do 16,3 CUI/mg. Čeprav so zaviralci tripsina znani kot antinutritivne sestavine, so dokazane tudi njihove pozitivne lastnosti. Na podlagi rezultatov raziskav je mogoče sklepati, da lahko grahor uspešno pridelujemo in uporabljamo za različne namene tako v Srbiji kot v Sloveniji.

Ključne besede: *Lathyrus sativus*, agrobiodiverziteta, diverzifikacija, produktivnost

Zahvala. Študijo so financirali ECPGR projekt EUGrainLeg in dva bilateralna projekta: 451-03-68/2022-14/200032 (Srbija) in BI-RS/23-25-042 (Slovenija).

Grahor / Grass pea

[11] Dr., Institute of Field and Vegetable Crops, Novi Sad, Serbia, e-pošta: aleksandra.savic@ifvcns.ns.ac.rs

Grass pea as a potential legume for diversification of Serbian and Slovenian agriculture

Although the grass pea (*Lathyrus sativus* L.) originates from the Mediterranean region, the Balkan Peninsula is considered to be the distribution route of this species in Europe. In the past, grass pea was a widespread and well-known species in the agriculture of the Western Balkans, including Serbia and Slovenia. Nowadays, it is only cultivated on small areas compared to other legumes and is considered an orphan crop. Due to its positive characteristics such as high protein content, resistance to drought and flooding, attempts have been made to reintroduce the grass pea into Serbian and Slovenian agricultural systems. Initially, the IFVCNS (Institute of Field and Vegetable Crops, Novi Sad) and KIS (Agricultural Institute of Slovenia) collections of grass peas were established and used for phenotypic and agronomic evaluation as part of the internationally recognized "EUGrainLeg" initiative.

The driving force for these activities was the emerging need to diversify agricultural systems and make them more sustainable by cultivating substitute or additional climate-adapted protein crops such as grass pea. In addition, this work has been extended through two bilateral collaborative projects related to genetic variability and the evaluation of nutritional traits, including antinutritive components of grass peas, such as protease inhibitors. In addition to a review of the work done in an attempt to explore and popularise the use of grass peas in the Western Balkans, this research presents the results of an initial field trail conducted in Serbia and Slovenia during the 2019 growing season on nine grass pea accessions, i.e. eight accessions from the Serbian and one from the Slovenian gene bank. The main productivity components (plant height, number of days to 50% flowering and maturity, number of pods per plant, seeds per pod, seeds per plant, 1000-seed weight) were evaluated. In general, all grass pea accessions performed satisfactory in these two environments, with minor differences. The vegetation period was the same (87 days to maturity) with a slightly shorter flowering phase in Slovenia. The greatest difference was observed in the number of pods per plant (28.1 and 9.2 pods per plant in Slovenia and Serbia, respectively), while the number of seeds per pod and seed yield per plant were similar (1.8 and 2.4 seeds per pod; 17.3 and 16.1 seed yield per plant in Serbia and Slovenia, respectively). In addition, the first screening of chymotrypsin inhibitors (CI) activity was performed on Serbian accessions, while it was yet to be measured on Slovenian germplasm. The CI activity ranged from 10.3 to 16.3 CUI/mg. Although trypsin inhibitors are known to be antinutritive components, their beneficial properties have been documented. From all these research results, it can be concluded that grass pea can be successfully cultivated and used for various purposes in both Serbia and Slovenia.

Keywords: *Lathyrus sativus*, agrobiodiversity, diversification, productivity

Acknowledgement. The study was funded by ECPGR project EUGrainLeg and two bilateral projects: 451-03-68/2022-14/200032 (Serbia) and BI-RS/23-25-042 (Slovenia).

Grass pea field trial at IFVCNS (author: M. Vasić, 2019)
Poljski poskus z grahorjem na IFVCNS (avtor: M. Vasić, 2019)

Javna služba v hmeljarstvu

Andreja ČERENAK[12], Barbara ČEH in Joško LIVK

V okviru javne službe (JS) v hmeljarstvu potekajo štiri strokovne naloge: Žlahtnjenje hmelja, Tehnologija pridelave in predelave hmelja, Introdukcija hmelja in Ocena letnika hmelja. Posebnost prvih dveh nalog je sofinanciranje pridelovalcev hmelja kar je edinstveno le za to JS. Glavni cilj strokovne naloge **Žlahtnjenje hmelja** je vzgoja lastnih sort hmelja, prilagojenih pridelavi v različnih pridelovalnih območjih Slovenije. Poleg visoke kakovosti pridelka za uporabo v pivovarski industriji je velik del naloge usmerjen v vzgojo sort, odpornih na glavne bolezni hmelja: hmeljevo peronosporo, hmeljevo pepelovko, verticilijsko uvelost hmelja in hudo viroidno zakrnelost hmelja. V zadnjih desetih letih je bilo na sortno listo vpisanih 9 sort, med katerimi se v pridelavi uveljavljata Styrian Wolf in Styrian Dragon.
Glavni cilj strokovne naloge **Tehnologije pridelave in predelave hmelja** je napovedovanje gospodarsko pomembnih bolezni in škodljivcev hmelja, spremljanju fenologije hmelja ter prognozah namakanja, gnojenja in tehnološke zrelosti. Glede na potrebe in zanimanje hmeljarjev ter stroke se v okviru naloge izvajajo tudi tehnološki poskusi. Vsako leto pripravimo seznam dovoljenih fitofarmacevtskih sredstev za varstvo hmelja v Sloveniji z vključeno maksimalno količino ostankov posameznih aktivnih snovi za posamezne svetovne trge, posebej tudi za ekološko pridelavo. Izvaja se sistemska analiza konkurenčnosti in svetovnih tržnih razmer, za tekoče leto pa se izdela modelna analiza variabilnih stroškov pridelave. Pripravljamo Hmeljarske informacije s tehnološkimi navodili/priporočili (15 do 20 vsako rastno sezono), ki jih ažurno pošiljamo hmeljarjem po e-pošti. S predavanji aktivno sodelujemo na tehnoloških sestankih hmeljarjev, ki potekajo med rastno sezono vsak drugi teden.
Strokovna naloga **Introdukcija novih in tujih sort hmelja** je osredotočena na določitev optimalne agrotehnike (čas rezi, napeljava poganjkov, gostota sajenja, gnojenje, dodatna opazovanja novih sort v poljskih razmerah s poudarkom na škodljivih organizmih …) domačih novih in tujih sort hmelja v naših pridelovalnih razmerah. Stalni cilji naloge so še ugotavljanje morebitnega pojava fiziopatij pri novih sortah in iskanje njihovega vzroka ter določevanje ustreznih rastnih razmer v naših pridelovalnih območjih za zanimive tuje sorte. Na nekaj let izvedemo posodobitev opisne sortne liste z novimi sortami, vpisanimi na slovensko sortno listo. Cilj je ponuditi slovenskim hmeljarjem potrebne informacije o novih slovenskih sortah in morebitnih tujih sortah za pridelovanje v naših razmerah.
Ocena letnika hmelja je strokovna naloga, s katero takoj po obiranju hmelja pridobimo podatke o skupnem slovenskem pridelku posameznih sort hmelja. Podatke lahko uporabijo hmeljarjem pri usmeritvi pridelave glede izbire sort hmelja, trgovci s hmeljem pa se na podlagi tega lahko hitreje in bolje odzovejo ter prilagodijo mednarodni ponudbi in povpraševanju. Kar 98 % pridelka hmelja se namreč izvozi. Namen naloge je tudi določitev kakovosti reprezentativnih vzorcev pridelka hmelja po posameznih sortah.

Ključne besede: javne službe, hmeljarstvo, hmelj

[12] Dr. Inštitut za hmeljarstvo in pivovarstvo Slovenije, e-pošta: andreja.cerenak@ihps.si

Public service in hop production

The Public Service (PS) in hop production consists of four professional tasks: Hop breeding, Technology of hop cultivation and processing, Introduction of new and foreign hop varieties, and Hop yield evaluation. A unique feature of the first two tasks is co-financing by hop growers. The main objective of the *Hop breeding* is to develop our own hop varieties that are suitable for cultivation in the various growing areas of Slovenia. In addition to the high quality of the crop for use in the brewing industry, a large part of the work is aimed at breeding varieties resistant to the main diseases: downy mildew, powdery mildew, verticillium wilt and severe hop stunt viroid disease. In the last ten years, 9 varieties have been added to the variety list, of which Styrian Wolf and Styrian Dragon are increasing their acreage.
The professional task *Technologies for the cultivation and processing of hops* focuses primarily on forecasting economically significant hop diseases and pests, monitoring hop phenology, and providing forecasts of irrigation, fertilization, and technological hop maturity. Based on the needs and interests of hop growers and the industry, technological trials are also conducted as part of the task. Every year, we prepare a list of authorised plant protection products for hop cultivation in Slovenia, including the maximum residue levels of individual active substances for various global markets, including organic production. A systematic analysis of competitiveness and global market conditions is carried out, and a model analysis of variable production costs is prepared for the current year. We produce *Hop Information* Bulletins with technological guidance/recommendations (15 to 20 per growing season), which are promptly e-mailed to hop growers. We actively participate through lectures in technological meetings for hop growers, held approximately every two weeks during the growing season.
The professional task *Introduction of new and foreign hop varieties* focuses on determining the optimum technology for cultivating new domestic and foreign hop varieties under our production conditions. This includes aspects such as pruning timing, shoot training, planting density, fertilization, and additional observations of new varieties under field conditions, with a focus on harmful organisms. Ongoing objectives include identifying the potential occurrence of physiopathies in new varieties and investigating their causes, as well as determining suitable growing conditions in our production areas for promising foreign varieties. Periodically, an updated descriptive variety list is prepared, incorporating new varieties registered in the Slovenian variety list. The aim is to provide Slovenian hop growers with essential information about new Slovenian and potential foreign hop varieties suitable for cultivation under our conditions.
The *Hop Year Assessment* is a professional task aimed at collecting data on the yield of individual hop varieties of Slovenian hop plantations after the harvest of the current season. This information can help hop growers to make production decisions regarding the choice of hop varieties, while hop traders can use it to respond more quickly and effectively to international supply and demand. This is particularly important as 98 % of the hop crop is exported. The task also includes determining the quality of representative hop yield samples for individual varieties.

Keywords: public services, hop production, hops

Labilni organski ogljik v tleh kot indikator intenzitete obdelave tal ter gnojenja

Ana SCHWARZMANN[13], Anton GOVEDNIK, Klemen ELER, Sara MAVSAR, Marjetka SUHADOLC in Rok MIHELIČ

Organski ogljik v tleh je eden izmed glavnih pokazateljev kakovosti tal. Obliko organskega ogljika, ki hitro mineralizira in je neposredno na voljo mikrobom za njihovo aktivnost, imenujemo labilni organski ogljik. Eden izmed načinov določanja labilnega organskega ogljika v tleh je oksidacija s kalijevim permanganatom, pri kateri dobimo s permanganatom oksidirajoči ogljik (POX-C). POX-C je dober pokazatelj sprememb v tleh, ki so posledica rabe tal, obdelave tal ali posevkov. Metoda za določanje POX-C je enostavna in poceni, kar predstavlja prednost v primerjavi z določanjem drugih frakcij ogljika. Možna je tudi terenska izvedba analize. Z meritvami POX-C med rastno sezono smo želeli preveriti, kako obdelava tal in gnojenje vplivata na to labilno frakcijo ogljika v tleh in če obstajajo sezonska nihanja ter povezave z drugimi merjenimi parametri.
POX-C smo preučevali na dolgoletnem poljskem poskusu »TillComp« v Ljubljani, kjer od leta 1999 primerjamo konvencionalno obdelavo tal (CT) in minimalno obdelavo, od leta 2017 preusmerjeno na no-till sistem (NT). Znotraj obeh načinov obdelave spremljamo učinke različnih načinov gnojenja: negnojena kontrola (CON), gnojenje z mineralnimi gnojili (MIN) in gnojenje s kompostom (ORG). Poskus je potekal leta 2023, ko je bila glavni posevek koruza. Tla smo med rastno sezono v globini 0–10 cm vzorčili šestnajstkrat. POX-C smo določili z ekstrakcijo z 0,2 M $KMnO_4$. Količino oksidiranega $KMnO_4$ smo določili spektrofotometrično in preračunali v količino labilnega ogljika. Sočasno smo spremljali tudi temperaturo tal, nasičenost por z vodo, nitrat, amonij, raztopljeni organski dušik, raztopljeni organski ogljik ter emisije CO_2 in N_2O.
Tako obdelava kot gnojenje sta vplivala na vsebnost POX-C v zgornjih 10 cm tal. Vsebnosti POX-C so bile skozi celotno rastno sezono največje na obravnavanju NT-ORG, kjer je sezonsko povprečje znašalo 1227 mg C/kg tal. V vseh preostalih obravnavanjih so bile vsebnosti statistično značilno manjše, v primeru obravnavanja CT-CON za 42,7 % (703 mg C/kg tal). Sezonska nihanja so bila podobna med obravnavanji. Opazili smo povezavo med POX-C in deležem por zapolnjenih z vodo (WFPS). Pri velikem WFPS so bile vsebnosti POX-C najvišje, kar se kaže tudi v negativni korelaciji med emisijami CO_2 in POX-C. Vzroke za to je potrebno še raziskati. Na podlagi obstoječega znanja je možno, da je bila zaradi anaerobnih pogojev aktivnost mikrobov omejena in zato zmanjšana poraba labilnih oblik ogljika, ali pa so v procesu fermentacije nastale topne organske spojine, ki jih zajamemo z analizo na POX-C. Podobno z drugimi raziskavami smo potrdili tudi tesno korelacijo med POX-C in skupnim organskim ogljikom v tleh, kar pomeni, da lahko na podlagi meritev POX-C ocenimo stanje organskega ogljika v tleh razmeroma hitro in poceni v primerjavi s standardno metodo suhega ali mokrega sežiga.

Ključne besede: organski ogljik, labilni ogljik, POX-C, kompost, no-till

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[13]Mag. inž. agr., Univerza v Ljubljani, Biotehniška fakulteta, e-pošta: ana.schwarzmann@bf.uni-lj.si

Labile soil organic carbon reflects the intensity of tillage and fertilisation

Soil organic carbon is one of the most important indicators of soil quality. The form of organic carbon that is rapidly mineralized and directly available to microbes for their activity is called labile organic carbon. One approach to determine the labile organic carbon in soil is to oxidize it with potassium permanganate to obtain permanganate-oxidizable carbon (POX-C). POX-C is a good indicator of changes in the soil resulting from land use, tillage or the introduction of cover crops. The method for determining POX-C is simple and inexpensive, which is an advantage over the determination of other carbon fractions. Field analysis is also possible. By measuring POX-C during the growing season, we wanted to investigate how tillage and fertilisation affect this labile fraction of soil carbon and whether there are seasonal variations and correlations with other measured parameters.
POX-C was investigated in the long-term field experiment "TillComp" in Ljubljana, Slovenia, where conventional tillage (CT) and minimum tillage, which was switched to no-tillage (NT) in 2017, have been compared since 1999. Within the two tillage variants, the effects of different fertilisation methods are observed: unfertilised control (CON), mineral fertilisation (MIN) and compost fertilisation (ORG). The experiment took place in 2023, when maize was the main crop. The soil was sampled 16 times during the growing season to a depth of 10 cm. POX-C was determined by extraction with 0,2 M $KMnO_4$. The amount of oxidized $KMnO_4$ was determined spectrophotometrically and calculated as the amount of labile carbon. At the same time, soil temperature, water-filled pore space, nitrate, ammonium, dissolved organic nitrogen, dissolved organic carbon, CO_2 and N_2O emissions were monitored.
Both tillage and fertilisation influenced the POX-C content in the top 10 cm of the soil. POX-C content was highest in NT-ORG throughout the growing season, where the seasonal average was 1227 mg C/kg soil. In all other treatments, the levels were significantly lower, in the case of the CT-CON treatment by 42,7% (703 mg C/kg soil). The seasonal variations between treatments were similar. We observed a correlation between POX-C and water-filled pore space (WFPS). POX-C values were highest at high WFPS, which is also reflected in the negative correlation between POX-C and CO_2 emissions. Why this is the case remains to be investigated. It is possible that microbial activity was limited due to the anaerobic conditions, so that the consumption of labile carbon forms was reduced. Another possibility is that soluble organic compounds formed during the fermentation process were detected in the POX-C analysis. In agreement with other studies, we also confirmed a close correlation between POX-C and total soil organic carbon, which means that based on POX-C measurements we can estimate the state of soil organic carbon relatively quickly and cost-effectively compared to complex laboratory dry or wet combustion methods.

Keywords: soil organic carbon, labile carbon, POX-C, compost, no-till

Acknowledgement. This work was funded under the CRP project ReC-Till (MKGP) and the EJP Soil Programme, project SOMMIT (EU, MKGP).

Vsebnost rastlinam dostopnega fosforja in kalija v kmetijskih tleh, analiziranih v centralnem laboratoriju Kmetijskega inštituta Slovenije med letoma 2006 in 2023

Matej ŠČUKA[14]

Fosfor in kalij sta ključni rastlinski hranili, ki neposredno vplivata na rodovitnost tal ter rast in razvoj rastlin. Študija predstavlja vsebnost rastlinam dostopnega kalija in fosforja v 13.174 vzorcih tal iz kontrole rodovitnosti tal (KRT), ki jo opravlja centralni laboratorij Kmetijskega inštituta Slovenije, ter v 2.694 vzorcih iz raziskovalnih projektov oddelka za kmetijsko ekologijo in naravne vire (OKENV) Kmetijskega inštituta Slovenije, izvedenih med leti 2006 in 2023. V študiji smo preučevali vsebnost rastlinam dostopnega fosforja (P_2O_5) in kalija (K_2O) na globini 0–30 cm, določenega po metodi ISO 11263:1994, v različnih tleh po vrstah kmetijske rabe - trajni travnik (1300), ostali trajni nasadi (1240), oljčnik (1230), ekstenzivni sadovnjak (1222), intenzivni sadovnjak (1221), vinograd (1211), rastlinjak (1190), hmeljišče (1160), njiva (1100). Študija je rezultat sistematičnega spremljanja, ohranjanja ter anonimne obdelave podatkov kontrole rodovitnosti za potrebe standardnega spremljanja stanja kmetijskih tal na nacionalni ravni, k čemur bo Slovenija zavezana z novo EU direktivo o zdravju tal. Ugotovitve prispevajo k razumevanju dinamike hranil v slovenskih tleh in so pomembne za razvoj trajnostnih praks v kmetijstvu. Študija poudarja pomen prilagojenega gnojenja ter ohranjanja talnih ekosistemov kot osnove za trajnostno kmetijsko proizvodnjo v Sloveniji. Kmetijska tla Slovenije so v povprečju dobro preskrbljena s kalijem, kar zmanjšuje potrebo po intenzivnem gnojenju s tem hranilom. V Sloveniji so v povprečju tla srednje preskrbljenosti do dobre preskrbljenosti z rastlinam dostopnim fosforjem. Preskrbljenost tal z rastlinam dostopnim fosforjem in kalijem je ovrednotena po smernicah za strokovno utemeljeno gnojenje (Mihelič in sod., 2010). Glede preskrbljenosti tal s kalijem najbolj izstopajo rastlinjaki, ki so v povprečju čezmerno preskrbljeni. Nekoliko slabše so preskrbljeni trajni travniki in ekstenzivni sadovnjaki, saj na njih poteka manj intenzivna pridelava. Ostale površine po posameznih rabah so v povprečju optimalno preskrbljene. Iz analiziranih vzorcev je razvidno tudi naravno ozadje preskrbljenosti tal s kalijem (glede na matično podlago). Slovenija je relativno bogata s kalijem, kar moramo upoštevati pri gnojenju. S fosforjem so tla v Sloveniji relativno dobro preskrbljena. V povprečju je večina tal ne glede na rabo optimalno preskrbljena do srednje preskrbljena. Stopnje preskrbljenosti tal s fosforjem po rabi kažejo na to, da so tla z intenzivno rabo, kot so vinogradi, njive in rastlinjaki, bolj preskrbljena s fosforjem, kar je posledica pogoste in intenzivne uporabe mineralnih gnojil. Med izbranimi rabami v naših podatkovnih bazah glede preskrbljenosti tal s fosforjem najbolj izstopajo hmeljišča s čezmerno preskrbljenostjo. Nasprotno pa so tla v bolj ekstenzivnih oblikah rabe, kot so travniki, oljčniki in ekstenzivni (visokodebelni) sadovnjaki, bolj srednje preskrbljena, kar je skladno z naravnimi procesi kroženja hranil in manj intenzivnim gnojenjem. Pri tem je razvidno, da so tla v Sloveniji, gledano iz naravnega ozadja glede na matično podlago, bolj siromašna s fosforjem v primerjavi s kalijem. Ustrezno upravljanje s fosforjem in kalijem ostaja ključno za ohranjanje dolgoročne rodovitnosti tal.

Ključne besede: fosfor, kalij, rodovitnost tal, upravljanje hranil, trajnostno kmetijstvo, Slovenija

[14] Mag. inž. agr., Kmetijski inštitut Slovenije, e-pošta: matej.scuka@kis.si

Plant-available phosphorus and potassium content of agricultural soils analysed in CL KIS (Central laboratory of the Institute of agriculture of Slovenia) between 2006 and 2023

Phosphorus and potassium are key plant nutrients that directly affect soil fertility and plant growth and development. This study presents the content of plant-available potassium and plant-available phosphorus in 13,174 soil samples from the Soil Fertility Test (KRT) carried out by the Central Laboratory of the Slovenian Agricultural Institute and 2,694 samples from research projects of the Agricultural Ecology and Natural Resources Department (OKENV) of the Slovenian Agricultural Institute carried out between 2006 and 2023. The study investigated the content of plant-available phosphorus (P_2O_5) and potassium (K_2O) at a depth of 0 to 30 cm, determined according to the ISO 11263 method: 1994, in different soils according to the type of agricultural use - permanent meadow (1300), other permanent crops (1240), olive orchard (1230), extensive orchard (1222), intensive orchard (1221), vineyard (1211), greenhouse (1190), hop field (1160), arable field (1100). The study is the result of a systematic monitoring, maintenance and anonymous processing of fertility control data for the purpose of standardised monitoring of agricultural soils at national level, to which Slovenia will be committed by the new EU Soil Health Directive. The findings contribute to the understanding of nutrient dynamics in Slovenian soils and are important for the development of sustainable practices in agriculture. The study highlights the importance of adapted fertilisation and soil ecosystem conservation as a basis for sustainable agricultural production in Slovenia. Slovenia's agricultural soils are on average well supplied with potassium, which reduces the need for intensive fertilisation with this nutrient, but are on average medium to well supplied with plant-available phosphorus. Soil phosphorus and potassium availability is evaluated according to the guidelines for scientifically based fertilisation (Mihelič et al., 2010). Greenhouses stand out the most in terms of potassium availability, as they are on average over-fertilised. Perennial grassland and extensive orchards are slightly less well supplied, as they are far less intensively farmed. Other areas are, on average, optimally stocked by land use. The samples analysed also show the natural background of soil potassium stocking (depending on the parent substrate). Slovenia is relatively rich in potassium, which must be taken into account when fertilising the soil with mineral fertilisers. Most soils in Slovenia are on average optimally to moderately phosphate-rich, irrespective of use. Soil phosphorus levels show that soils with intensive land use, such as vineyards, arable land and greenhouses, are more phosphorus-rich, due to the frequent and intensive use of mineral fertilisers. Among the selected land use in our databases, hop fields stand out the most in terms of phosphorus loading. In contrast, soils in more extensive land uses, such as meadows, olive groves and extensive (high stemmed) orchards, are more moderately phosphorus loaded, which is consistent with natural nutrient cycling processes and less intensive fertilisation. It can be seen here that soils in Slovenia are more depleted in phosphorus compared to potassium, when viewed from a natural background relative to the parent material. Appropriate phosphorus and potassium management remains the key to maintaining long-term soil fertility.

Keywords: phosphorus, potassium, soil fertility, nutrient management, sustainable agriculture, Slovenia

Vpliv obdelave tal na zaloge organskega ogljika: ocene emisijskih faktorjev iz dolgoletnih poljskih poskusov

Kristina OCVIRK [15], Rok MIHELIČ in Marjetka SUHADOLC

Kmetijstvo ima pomembno vlogo pri blaženju podnebnih sprememb, saj tla predstavljajo enega največjih ponorov ogljika na Zemlji. Znano je, da spremembe v rabi zemljišč in kmetijskih praksah, kot so obdelava tal, gnojenje, kolobarjenje, uporaba prekrivnih dosevkov, gospodarjenje z žetvenimi ostanki idr., pomembno vplivajo na zaloge ogljika v tleh (SOC). Optimizacija teh praks lahko prispeva k sekvestraciji C, to je povečanju zalog SOC in zmanjšanju emisij toplogrednih plinov. Kljub optimizmu glede prispevka kmetijstva pri doseganju podnebnih ciljev še vedno nimamo celovite ocene, kako posamezne kmetijske prakse vplivajo na povečanje zalog organskega ogljika v tleh v različnih pedo-klimatskih razmerah. Sekvestracija ogljika se namreč lahko močno razlikuje glede na tip tal in podnebne razmere, kar pomeni, da je potrebna prilagoditev kmetijskih praks specifičnim lokalnim razmeram. Za oceno potenciala sekvestracije ogljika z različnimi kmetijskimi praksami smo uporabili pristop emisijskih faktorjev (EF) (IPCC 2006) in EJP SOIL CarboSeq podatkovno zbirko dolgoletnih poljskih poskusov (dostopna na: https://doi.org/10.5281/zenodo.8130174). Relativni EF je razmerje med zalogami SOC v referenčnem (sedanja kmetijska praksa) in zalogami SOC v alternativnem scenariju (kmetijska praksa, ki jo želimo preveriti). Relativni EF posamezne alternativne prakse, ki je večji od 1, pomeni povečanje zalog SOC, medtem ko vrednost manjša od 1, odraža zmanjšanje zalog v primerjavi z referenčno kmetijsko prakso. Zaloge ogljika smo izračunali na osnovi koncentracij SOC in volumske gostote. Uporabili smo podatke evropskih poskusov starejših od 5 let (5-36 let) do globine 30 cm in slovenskih poskusov do globine 20 cm po 20 letih zmanjšane intenzitete obdelave. Ker smo se v prispevku osredotočili na učinke obdelave tal, smo zaloge SOC izračunali tudi po pristopu ekvivalentne mase tal (ESM), ki uporablja maso tal kot korekcijsko merilo. Na ta način smo se izognili morebitnim napakam, ki jih povzroči sprememba volumske gostote zaradi obdelave tal. Na osnovi podatkov dolgoletnih evropskih poskusov smo ugotovili, da je povprečna vrednost relativnega EF tako za minimalno obdelavo brez obračanja tal (*non-inversion tillage*) kot za direktno setev (*no-till*) značilno večja od 1 (Panagea in sod., 2023). Natančneje, relativni EF za direktno setev je bil 1,14 (SD ±0,25) oz. 1,11 (SD ±0,19) z uporabo pristopa ESM. Za minimalno obdelavo brez obračanja tal je bil relativni EF 1,05 (SD ±0,18) oz. 1,03 (SD ±0,12) po metodi ESM. Rezultati za obe praksi se dobro ujemajo z globalnimi ocenami, za katere IPCC navaja EF za direktno setev 1,1 in za minimalno obdelavo brez obračanja tal 1,05. Relativni EF, ocenjen za slovenske dolgoletne poskuse, potrjujejo ugotovitve drugih študij, da imajo specifične lokalne pedo-klimatske razmere velik vpliv na potencial sekvestracije ogljika. Relativni EF dolgoletnega poskusa v Ljubljani (Till-Comp) na teksturno težjih tleh je nekoliko nad evropskim povprečjem, zlasti pri obravnavanjih z organskim gnojenjem (1,42) in pri kontroli (brez gnojenja) (1,24). Nasprotno pa je EF dolgoletnega poskusa Rašica v Moškanjcih na teksturno lažjih tleh z minimalno obdelavo brez obračanja tal manjši v primerjavi z evropskim povprečjem (0,97). Pet let po uvedbi ekološke pridelave pa se je EF povečal na 1,03 oziroma 1,06 pri izračunu zalog SOC po metodi ESM. Tako direktna setev kot minimalna obdelava brez obračanja tal imata potencial za povečanje zalog organskega ogljika v tleh, vendar je obseg učinka odvisen tako od specifičnih pedo-klimatskih pogojev lokacije kot tudi kombinacije z drugimi kmetijskimi praksami.

Ključne besede: sekvestracija ogljika, direktna setev, *no-till*, minimalna obdelava tal
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[15] Univerza v Ljubljani, Biotehniška fakulteta, e-pošta: kristina.ocvirk@bf.uni-lj.si

Effects of soil tillage on SOC stocks: emission factor estimates from long-term field experiments

Agriculture plays an important role in mitigating climate change, as soils are one of the largest carbon sinks on Earth. Changes in land use and agricultural practices such as tillage, fertilisation, crop rotation, use of cover crops, harvest residue management and others are known to have significant impacts on soil organic carbon stocks (SOC). Optimising these practices can contribute to C sequestration, i.e. increasing SOC stocks and reducing GHG emissions. Despite optimism about the contribution of agriculture to climate goals, we still do not have a comprehensive assessment of the effect of individual agricultural practices on the increase of soil organic carbon stocks under different pedoclimatic conditions. Indeed, carbon sequestration can vary considerably depending on soil type and climatic conditions, which implies the need to adapt agricultural practices to specific local conditions.

To estimate the carbon sequestration potential of different agricultural practices, we used the Emission Factor (EF) approach (IPCC 2006) and the EJP SOIL CarboSeq database of long-term field experiments (available at: https://doi.org/10.5281/zenodo.8130174). Relative EF is the ratio of SOC stocks in the reference (current agricultural practice) to the SOC stocks in the alternative scenario (the agricultural practice tested). Relative EF of a particular alternative practice greater than 1 represents an increase in SOC stocks, while a value less than 1 reflects a decrease in stocks compared to the reference agricultural practice. Carbon stocks were calculated based on SOC concentration and bulk density. We used data from European trials older than 5 years (5-36 years) and to a depth of 30 cm and Slovenian trials to a depth of 20 cm after 21 years of reduced tillage intensity. As we focused on the effects of tillage here, we also calculated SOC stocks using the equivalent soil mass (ESM) approach, which uses soil mass as a correction criterion. In this way, we avoided potential errors caused by changes in bulk density due to tillage.

Based on data from European long-term experiments, we found that the mean relative EF for both minimum non-inversion tillage and no-till was significantly greater than 1 (Panagea in sod., 2023). Specifically, the relative EF for no-till was 1.14 (SD ±0.25) and 1.11 (SD ±0.19) using the ESM approach. For minimum non-inversion tillage, the relative EF was 1.05 (SD ±0.18) and 1.03 (SD ±0.12) using the ESM approach. The results for both practices are in good agreement with global estimates, IPCC for example gives an EF of 1.1 for no-till and of 1.05 for minimum tillage. Relative EFs for Slovenian long-term experiments confirm that specific local pedoclimatic conditions have major impact on the carbon sequestration potential. Relative EF of the Ljubljana long-term experiment (Till-Comp) is slightly above the European average, especially for the treatments with organic fertiliser (1.42) and for the control (no fertiliser) (1.24). In contrast, the EF of the long-term experiment Rašica in Moškanjci, with minimum non-inversion tillage is lower than the European average at 0.97. Five years after the introduction of organic management, this has risen to 1.03 and 1.06 respectively when calculating stocks with ESM.

Both no-till and minimum non-inversion tillage have the potential to increase soil organic carbon stocks, but the magnitude of the effect depends both on the specific pedoclimatic conditions of the site and on the combination with other agricultural practices.

Keywords: carbon sequestration, no-till, minimal tillage

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Zaloge organskega ogljika v tleh glede na kmetijsko rabo tal v Sloveniji

Žan RIJAVEC[16] in Matej ŠČUKA

Vsebnost organskega ogljika v tleh (SOC) ima ključno vlogo pri ohranjanju rodovitnosti tal, njihovi strukturni stabilnosti in sposobnosti zadrževanja vode. SOC pomembno prispeva k blaženju podnebnih sprememb, saj deluje kot ponor ogljika. Sestavljajo ga različne organske spojine, ki izvirajo iz razgradnje rastlinskih ostankov, mikrobne biomase in živalskih ostankov. Količina SOC v tleh je tesno povezana z rabo tal in kmetijskimi praksami. Intenzivne kmetijske prakse, kot so globoko oranje, monokulturna pridelava in uporaba mineralnih gnojil, vodijo do zmanjšanja zalog SOC zaradi pospešene mineralizacije organske snovi in povečanih emisij CO_2. Trajnostne prakse, kot so ohranitvena obdelava tal, kolobarjenje in vključevanje prekrivnih rastlin, prispevajo k povečanju zalog SOC, kar pozitivno vpliva na kakovost tal in zmanjšuje vpliv kmetijstva na podnebne spremembe. Raziskava, katere cilj je bil preučiti vpliv različnih oblik rabe tal na zaloge SOC v kmetijskih tleh Slovenije, je potekala v obdobju med letoma 2016 in 2021. Analizirali smo 1438 vzorcev tal, odvzetih na 485 lokacijah, ki so zajemale različne rabe kmetijskih površin: njive, trajne travnike, vinograde, intenzivne in ekstenzivne sadovnjake ter površi ne v zaraščanju. Vzorci so bili razdeljeni na tri globinske sloje (0–10 cm, 10–20 cm, 20–30 cm). Rezultati raziskave kažejo, da se povprečne vrednosti SOC v zgornji plasti tal (0–10 cm) gibljejo med 26 t/ha (vinograd - VI) in 72 t/ha (barjanski travnik - BT), glede na rabo tal so zaloge ogljika najvišje v zgornjih horizontih (0–10 cm) ter z globino padajo. Rahlo nižja vrednost v zgornjem sloju v primerjavi z nižje ležečimi sloji je določena na njivskih površinah (33 t/ha). Največji upad zalog ogljika v drugem sloju tal zasledimo pri rabah, kjer ni intenzivnega mešanja slojev tal. Vrednosti SOC v drugem sloju tal (10–20 cm) znašajo med 18 t/ha (VI) in 66 (BT) t/ha. Na globini med 20 in 30 cm znašajo povprečne zaloga zaloge SOC med 16 t/ha (VI) in 52 t/ha (BT). Barjanski travniki imajo najvišje zaloge SOC, kar je posledica anaerobnih razmer, ki upočasnjujejo razgradnjo organske snovi in omogočajo dolgotrajno shranjevanje ogljika. Trajni travniki (TR) in ekstenzivni sadovnjaki (ES) prav tako kažejo visoke vrednosti SOC, kar je mogoče pripisati trajni vegetacijski pokritosti in nizki intenzivnosti obdelave tal. Intenzivni sadovnjaki (IS) in njive (NJ) kažejo nižje zaloge SOC, predvsem zaradi intenzivne obdelave tal, ki pospešuje razgradnjo organske snovi in zmanjšuje vsebnost ogljika v zgornjih slojih. Vinogradi imajo najnižje vrednosti SOC, kar je povezano s pogosto obdelavo in majhnim vnosom organskega materiala. Iz rezultatov lahko sklepamo, da ima način rabe tal odločilen vpliv na zaloge SOC.

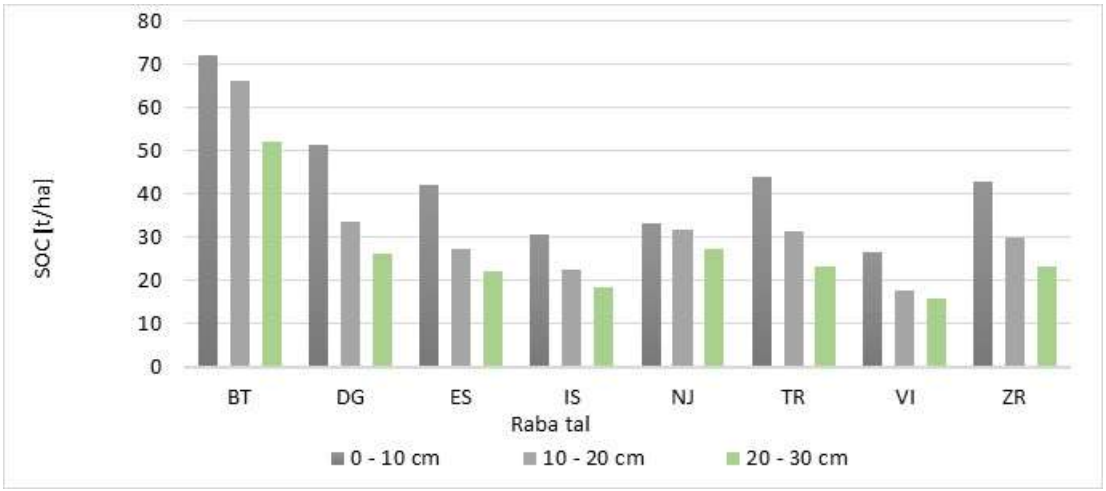
Ključne besede: organski ogljik v tleh, trajnostno kmetovanje, raba tal, emisije CO_2

[16] Mag. inž. agr., Kmetijski inštitut Slovenije, e-pošta: Zan.Rijavec@kis.si

Soil organic carbon stocks according to agricultural land use in Slovenia

Soil organic carbon (SOC) plays a key role in maintaining soil fertility, structural stability and water retention capacity. SOC contributes significantly to climate change mitigation by acting as a carbon sink. It is composed of various organic compounds derived from the decomposition of plant residues, microbial biomass and animal remains. The amount of SOC in the soil is closely linked to land use and agricultural practises. Intensive agricultural practises such as deep tillage, monocultures and the use of synthetic fertilisers lead to a decline in SOC stocks due to accelerated mineralisation of organic matter and increased CO_2 emissions. Sustainable practises such as conservation tillage, crop rotation and the inclusion of cover crops contribute to an increase in SOC stocks, which has a positive impact on soil quality and reduces the impact of agriculture on climate change. The research was conducted between 2016 and 2021 and aimed to investigate the effects of different forms of land use on SOC stocks in agricultural soils in Slovenia. We analysed 1438 soil samples from 485 sites covering different types of agricultural land: Arable land, permanent grassland, vineyards, intensive and extensive orchards and overgrown areas. The samples were divided into three depth layers (0–10 cm, 10–20 cm, 20–30 cm). The results of the study show that the average SOC values in the upper soil layer (0–10 cm) range from 26.45 t/ha in vineyards to 72.03 t/ha in moorland meadows. Peat meadows have the highest SOC stocks, which is a consequence of the anaerobic conditions that slow down the decomposition of organic matter and enable long-term carbon storage. Permanent grassland (52.87 tonnes/ha) and extensive orchards (47.62 tonnes/ha) also have high SOC values, which can be attributed to the permanent vegetation cover and the low intensity of tillage. Intensive orchards (35.21 t/ha) and arable land (32.14 t/ha) have lower SOC values, mainly due to intensive tillage, which accelerates the decomposition of organic matter and reduces the carbon content in the upper layers. Vineyards have the lowest SOC values, which is related to frequent ploughing and low input of organic matter. From the results we can conclude that the type of land use has a decisive influence on the SOC stock.

Keywords: soil organic carbon, sustainable agriculture, land use, CO_2 emissions



SOC (t/ha) po rabah tal glede na globino tal / SOC (t/ha) by land use (raba tal) depending on soil depth.

Ekološko varstvo hmelja (*Humulus lupulus* L.) s poudarkom na zmanjševanju populacije škodljivcev

Magda RAK CIZEJ[17], Franček POLIČNIK, Monika OSET LUSKAR in Octave LACROIX

Hmelj (*Humulus lupulus* L.) je večletna rastlina, ki se goji predvsem za namene pivovarske industrije, manjši delež se uporabi tudi za čaje in za kozmetične namene. Kot pri vseh drugih panogah kmetijstva je tudi v hmeljarstvu povpraševanje po ekološko pridelanem hmelju. Hmelj je gostitelj mnogih bolezni in škodljivcev. V prispevku se bomo osredotočili na ekološko varstvo hmelja s poudarkom na obvladovanju škodljivcev hmelja. Škodljivci, ki se na hmelju pojavljajo vsako leto, so: hmeljeva listna uš (*Phorodon humuli*), hmeljeva (navadna) pršica (*Tetranychus urticae*), hmeljev bolhač (*Psylliodes attenuatus*), koruzna vešča (*Ostrinia nubilalis*), hmeljev rilčkar (*Neoplinthus tigratus porcatus*).
Obvladovanje škodljivcev na hmelju je v okviru integriranega varstva rastlin velik izziv, saj nimamo veliko dovoljenih insekticidov in akaricidov za uporabo. Pri ekološkem varstvu so sintetični insekticidi in akaricidi prepovedani, zato za zmanjševanje populacije škodljivcev uporabljamo npr. rastlinske izvlečke, različne alge, močila, pripravke na osnovi *Bacillus thuringiensis* in sredstva, ki omejujejo napad, kot je npr. kaolin, in druge.
Vse pogosteje uporabljamo predatorje, plenilce. Tako smo za obvladovanje hmeljeve (navadne) pršice v rastlinjakih, kjer se prideluje certificiran sadilni material hmelja, uporabili plenilsko pršico *Amblyseius andersoni,* ki smo jo večkrat vnesli, in bili zelo uspešni. V hmeljišču smo za zatiranje pršice uporabili plenilsko pršico *Neoseiulus californicus*. Glede na dejstvo, da je na seznamu domorodnih vrst koristnih organizmov parazitoidna osica *Trichogramma brassicae*, ki uspešno parazitira jajčeca različnih metuljev, jo bomo v prihodnje vnesli v hmeljišča za zatiranje koruzne vešče.
V bodoče je pred nami še mnogo izzivov za uspešno obvladovanje škodljivcev hmelja v okviru ekološkega varstva.

Ključne besede: hmelj, *Humulus lupulus*, škodljivci, hmeljeva (navadna) pršica, ekološko varstvo, *Amblyseius andersoni, Neoseiulus californicus*

Zahvala. Raziskava se financira v okviru projekta EIP EKOHMELJ.

Nanos plenilske pršice Amblyseius andersoni na sadike hmelja v rastlinjaku
Application of predatory mite Amblyseius andersoni on hop seedlings in a greenhouse

[17] Dr., Inštitut za hmeljarstvo in pivovarstvo Slovenije, e-pošta: magda.rak-cizej@ihps.si

Organic protection of hops (*Humulus lupulus* L.) with an emphasis on reducing pest populations

Hops (*Humulus lupulus* L.) is a perennial plant primarily cultivated for the brewing industry, with smaller quantities used for teas and cosmetic purposes. As in other agricultural sectors, there is a growing demand for organically produced hops in hop cultivation. This article focuses on the ecological protection of hops, with an emphasis on pest management. Hops are hosts to many diseases and pests. The pests that occur annually in hop fields are: damson-hop aphid (*Phorodon humuli*), two-spotted spider mite (*Tetranychus urticae*), hop flea beetle (*Psylliodes attenuatus*), European corn borer (*Ostrinia nubilalis*), hop weevil (*Neoplinthus tigratus porcatus*).
Managing pests in hops is a significant challenge in integrated pest management, as there are limited approved insecticides and acaricides available for use on hops. In organic production, synthetic insecticides and acaricides are prohibited. Thus, alternative methods are used to reduce pest populations, including plant extracts, various algae, adjuvants, preparations based on *Bacillus thuringiensis*, substances that limit pest attacks (e.g., kaolin), and others.
The use of predators and natural enemies is becoming increasingly common. For example, to control two-spotted spider mites in greenhouses producing certified hop seedling material, the predatory mite *Amblyseius andersoni* was applied multiple times with great success. In hop fields, the predatory mite *Neoseiulus californicus* was used to manage hop spider mites.
Considering the presence of the native parasitoid wasp *Trichogramma brassicae* on the list of beneficial organisms, which effectively parasitizes the eggs of various moths, it will be introduced into hop fields in the future to management the European corn borer.
In the future, many challenges lie ahead for the successful management of hop pests within the framework of organic farming.

Keywords: Hops, *Humulus lupulus*, pests, two-spotted spider mites, ecological protection, *Amblyseius andersoni, Neoseiulus californicus*

Acknowledgments: The research is funded as part of the EIP EKOHMELJ project.

Parazitoidna osica Trichogramma brassicae.

The parasitoid wasp Trichogramma brassicae.

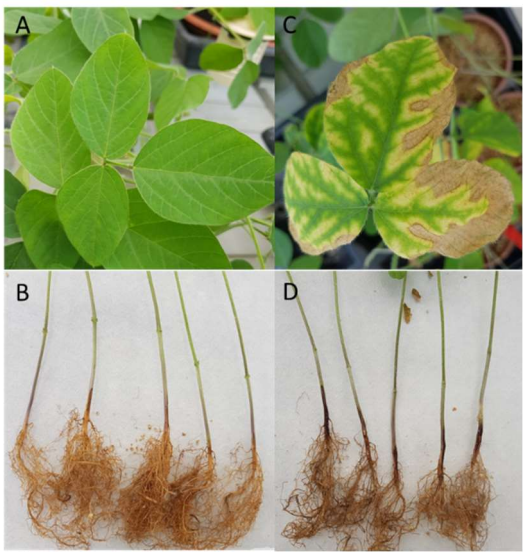
Pojavi novih glivičnih povzročiteljev bolezni rastlin v Sloveniji

Urša PRISLAN[18], Eva KOVAČEC, Aleksandra PODBOJ RONTA, Hans-Josef SCHROERS in Janja ZAJC ŽUNIČ

V luči podnebnih sprememb in globalizacije se kmetijstvo sooča z vse večjimi izzivi, med njimi tudi s pojavom novih glivičnih povzročiteljev bolezni. Ti s sabo prinašajo nepoznane vplive na pridelovanje kulturnih kmetijskih rastlin in lahko spreminjajo vedenje že prisotnih in poznanih rastlinskih patogenov. V mikološkem laboratoriju Oddelka za varstvo rastlin Kmetijskega inštituta Slovenije vsako leto v sklopu diagnostične in strokovne dejavnosti analiziramo številne vzorce, na katerih je mogoče opaziti pojavljanje novih rastlinskih patogenov, ki prej v našem okolju niso bili poznani. V prispevku predstavljamo izbor novih potrjenih glivičnih in glivam podobnih povzročiteljev bolezni.

Oomiceta *Globisporangium* (*Pythium) mastophorum* je bila izolirana iz vzorca peteršilja s pridelovalne površine s 30 % incidenco odmiranja sadik. Ta patogen pomembno vpliva na pridelavo peteršilja, okužene sadike pa predstavljajo tveganje za širjenje patogena na neokužena polja in zasebne vrtove. Iz bolezenskih znakov listov in gomoljev sladkega krompirja so bile izolirane nekatere glive, ki predstavljajo prve najdbe v Sloveniji in celo v Evropi (npr. *Didymella americana*). Sladki krompir, ki je čedalje bolj zanimiva poljščina za pridelavo, zaradi dokaj enostavnega načina vegetativnega razmnoževanja predstavlja veliko tveganje za vnos novih rastlinskih patogenov, ki lahko potencialno okužujejo tudi druge kmetijske rastline. Iz nekrotičnih listov fižola perujskega izvora je bila prvič v Evropi potrjena gliva *Colletotrichum incanum,* za katero smo pokazali, da povzroča znake antraknoze. Na gojeni soji v Sloveniji z znaki nenadne smrti, smo na propadlih koreninah potrdili novo vrsto rodu Fusarium, za katero smo pokazali, da je patogen soje kot tudi fižola, kar lahko pomembno vpliva na pridelavo te pomembne poljščine.

Prihodnost prinaša številne izzive na področju varstva rastlin in prihodu novih patogenov se ni mogoče povsem izogniti. Prav zato je njihovo zgodnje odkrivanje z novimi in bolj občutljivimi diagnostičnimi orodji izrednega pomena za učinkovito ukrepanje.



Zdravi listi (A) in korenine (B) ter znaki okužbe z novo vrsto Fusarium sp. na listih (C) in koreninah (D) soje (Glycine max (L.) Merr.).

Healthy leaves (A) and roots (B), and symptoms of infection by the new Fusarium sp. species on leaves (C) and roots (D) of soybean (Glycine max (L.) Merr.).

Ključne besede: tujerodne glive, gospodarsko pomembne glive, prva odkritja, bolezni rastlin

[18] Mag. inž. hort., Kmetijski inštitut Slovenije, e-pošta: ursa.prislan@kis.si

Emergence of new fungal agents of plant diseases in Slovenia

In light of climate change and globalization, agriculture is facing increasing challenges, including the emergence of new fungal pathogens. These pathogens bring unknown impacts on the cultivation of agricultural crops and may alter the behavior of existing and well-known plant pathogens. Each year, the mycological laboratory at the Plant Protection Department of Agricultural Institute of Slovenia analyzes numerous samples as part of its diagnostic and professional activities, where the appearance of new plant pathogens, previously unknown in our environment, is observed. A selection of newly confirmed fungal and fungal-like pathogens will be presented.

The oomycete *Globisporangium (Pythium) mastophorum* was isolated from a parsley sample taken from a production area with a 30% incidence of seedling damping-off. This pathogen significantly affects parsley production, and infected seedlings pose a risk for spreading the pathogen to uninfected fields and private gardens. From the disease symptoms on the leaves and tubers of sweet potatoes, several fungi were isolated that represent the first finds in Slovenia and even Europe (e.g., *Didymella americana*). Sweet potato, which is an increasingly popular crop for cultivation, presents a high risk for the introduction of new plant pathogens due to its relatively easy method of vegetative propagation, which could potentially infect other agricultural crops as well. From necrotic leaves of beans of Peruvian origin the fungus *Colletotrichum incanum*, that causes anthracnose, was confirmed for the first time in Europe. On cultivated soybeans in Slovenia, showing sudden death syndrome symptoms, a new species of the genus Fusarium was confirmed on decayed roots. We demonstrated that this pathogen affects both soybeans and beans, which could significantly impact the production of this important crop.

The future brings numerous challenges in plant protection, and the arrival of new pathogens cannot be entirely avoided. Therefore, their early detection with new and more sensitive diagnostic tools is of critical importance for effective response.

Keywords: alien fungi, economically important fungi, first discoveries, plant diseases

Biotično zatiranje invazivnega plevela pelinolistne ambrozije (*Ambrosia artemisiifolia* L.) s hroščem ambrozijevim lepencem (*Ophraella communa* LeSage) (Coleoptera)

Igor NEKREP[19], Špela MODIC, Jaka RAZINGER, Tina CERAR, Eva PRAPROTNIK, Primož ŽIGON, Branislav PEŠIĆ, Klara GAJŠEK, Sergej PRAČEK, Tjaša ŠENTJURC, Anže ROVANŠEK, Robert LESKOVŠEK, Dóra IVÁNYI, Zita DORNER, Urs SCHAFFNER in Stefan TOEPFER

Pelinolistna ambrozija (*Ambrosia artemisiifolia* L.) je trdovratna tujerodna invazivna rastlina z alergenim pelodom. Kot plevelna vrsta lahko znatno zmanjša pridelek gojenih rastlin, kar ima pomembne gospodarske posledice za kmetijstvo. Je edina rastlinska vrsta v Sloveniji in drugih centralno evropskih državah, ki jo je potrebno obvezno odstranjevati oziroma zatirati na vseh območjih, kjer se pojavlja. Uporaba herbicidov ali košnja žarišč ambrozije sta zahtevna in pogosto nemogoča, zato je biotično zatiranje obetavna alternativa. Ena od možnosti je uporaba ambrozijevega lepenca (*Ophraella communa* LeSage, 1986) (Coleoptera: Chrysomelidae), naravnega sovražnika ambrozije, ki se z njo prehranjuje. Hrošč in njegova gostiteljska rastlina izvirata iz Severne Amerike. V Evropi je bil prvič zabeležen leta 2013 v Italiji, v Sloveniji pa leta 2017. Od takrat se je razširil proti vzhodu do Romunije ter proti zahodu do Francije. V letu 2023 smo izvedli poskuse v kletkah na prostem (mikroplotih) na dveh lokacijah z različnimi pedo-klimatskimi razmerami (Ljubljana in Gradišče pri Vipavi) za preučevanje učinkovitosti biotičnega zatiranja ambrozije v različnih razmerah. Na posamezni lokaciji smo postavili štiri kletke, velikosti 2 × 1 × 1 m, ki so bile prekrite z mrežo, skozi katero hrošči niso mogli prehajati. V mesecu maju smo na obeh lokacijah v kletki 1 in 2 posadili 12 mladih rastlin ambrozije in v vsako naselili šest hroščev (tri samce in tri samice). V kletki 3 in 4 smo posadili po sedem rastlin in vanju nismo izpustili hroščev. Obravnavali smo ju kot negativni kontroli, da smo lahko opazovali in beležili razvoj nenapadene ambrozije. Skozi celotno sezono od maja do sredine oktobra smo tedensko spremljali razvoj populacije lepenca, beležili število odloženih jajčec, ličink treh stopenj, bub ter odraslih osebkov. Hrošče naslednjih generacij smo označevali z različnimi barvami glede na generacijo. Poleg tega smo spremljali razvoj posameznih rastlin ambrozije, vključno z višino, širino, številom listov in cvetov, prisotnostjo peloda, stopnjo objedenosti ter sušenjem rastlin, da bi ocenili vpliv objedanja hroščev. Rezultati so pokazali, da so hrošči razvili tri generacije na obeh lokacijah. Objedenost rastlin z lepencem je bila na lokaciji Gradišče v avgustu in septembru v povprečju za 44 % višja v primerjavi z rastlinami v kontroli, medtem ko rastline na lokaciji Ljubljana v primerjavi s kontrolo v povprečju niso bile bolj poškodovane. To je verjetno posledica vpliva polžev, vremenskih razmer in manjše populacije hroščev na tej lokaciji. Ne glede na lokacijo je populacija hroščev v primerljivi meri zmanjšala cvetenje, tvorbo peloda in semen rastlin. Nadaljevali bomo s poskusi, da bi lahko podali natančnejšo oceno potenciala lepenca za namene biotičnega varstva pri zatiranju te invazivne plevelne vrste v Sloveniji in sosednjih državah.

Ključne besede: pelinolistna ambrozija, *Ambrosia artemisiifolia*, biotično varstvo, ambrozijev lepenec, *Ophraella communa*

Zahvala. Raziskava se financira iz projekta Horizon Europe ADOPT-IPM „EU-CHINA joint action to increase development and adoption of IPM tools" (10106430: HORIZON-CL6-2021-FARM2FORK-01).

[19] Univ. dipl. biol., Kmetijski inštitut Slovenije, Oddelek za varstvo rastlin, e-pošta: igor.nekrep@kis.si

The biological control of the invasive common ragweed (*Ambrosia artemisiifolia* L.) with the ragweed leaf beetle (*Ophraella communa* LeSage) (Coleoptera)

Common ragweed (*Ambrosia artemisiifolia* L.) is a persistent invasive alien plant species with allergenic pollen. As a weed, it significantly reduces crop yields on agricultural land, resulting in economic impact on agriculture. It is the only plant species in Slovenia and other central European countries that requires mandatory removal or control by landowners wherever it occurs. Herbicide application or mowing of ragweed hotspots is laborious and often not possible. Biological control is therefore a promising alternative. One possible approach is the use of the ragweed leaf beetle (*Ophraella communa* LeSage, 1986) (Coleoptera: Chrysomelidae), a natural enemy of ragweed that feeds on the plant. The beetle originates, as also the ragweed, from North America. In Europe, it was first reported in Italy in 2013 and in Slovenia in 2017. Since then, the beetle has spread eastwards to Romania and westwards to France. In 2023, we conducted field-cage trials (microplots) at two locations (Ljubljana and Gradišče pri Vipavi) under two different pedo-climatic conditions to test the effectiveness of ragweed biological control under such different conditions. Four cages measuring 2 × 1 × 1 m were set up at each location and covered with a net to prevent the beetles from escaping. In May, 12 young ragweed plants were planted in cages 1 and 2 at each site, and six beetles (three males and three females) were released into each cage. In cages 3 and 4, we planted seven plants and did not release any beetles. These served as negative controls, allowing us to observe and record the normal development of ragweed. Throughout the growing season from May until mid-October, we monitored the development of the beetle population on a weekly basis and recording the number of eggs, larvae in all three instars, pupae, and adults. We also marked subsequent generations of beetles with different colors to track their lineage. In addition, we assessed ragweed plant development, including height, width, number of leaves and flowers, pollen shedding, defoliation and signs of plant wilting, to assess the impact of the beetles. The results showed that the beetles developed 3 generations at both sites. In August and September the beetle-infested plants at the Gradišče site were on average 44% more defoliated than the control plants, while the plants at the Ljubljana site did not show significantly more damage compared to the control. This is likely primarily due to the impact of slugs, weather conditions, and the smaller beetle population at this location. However, regardless of the location, the beetle population comparably reduced some flowering, pollen production and seed formation. We will proceed with the experiments to finally provide a precise estimate of the biocontrol power of this agent in managing this invasive weed in Slovenia and neighboring countries. We acknowledge funding from the Horizon Europe project ADOPT-IPM „EU-CHINA joint action to increase development and adoption of IPM tools” (10106430: HORIZON-CL6-2021-FARM2FORK-01).

Keywords: common ragweed, *Ambrosia artemisiifolia*, biological control, ragweed leaf beetle, *Ophraella communa*

Proučevanje občutljivosti slovenskih hibridov zelja (*Brassica oleracea* var. *capitata* L.) na okužbo s črno žilavko kapusnic (*Xanthomonas campestris* pv. *campestris)*

Primož FABJAN[20], Adriana PODRŽAJ, Helena VOLK in Katarina RUDOLF PILIH[21]

Bakterija *Xanthomonas campestris* pv. *campestris* (Xcc) pri zelju in ostalih kapusnicah povzroča bolezen, imenovano črna žilavka. Za bolezen je značilno rumenenje listnih robov v obliki črke V, opazimo tipično črnenje žil, kasneje počrni tudi sredica glav. Obolelo zelje ni primerno za prodajo ali predelavo. V okviru Javne službe v vrtnarstvu (JSV) poteka žlahtnjenje hibridnih sort tako s klasičnimi kot tudi biotehnološkimi pristopi in vključuje pridobivanje čistih linij, testiranje kombinacijskih sposobnosti ter izbiro najboljših hibridov. Izbranim hibridom poleg morfoloških znakov določimo tudi poljsko odpornost na črno žilavko kapusnic. V tem povzetku predstavljamo pilotno raziskavo, ki smo jo z namenom vzpostavitve učinkovitega protokola ugotavljanja odpornosti hibridov zelja na Xcc izvedli na Biotehniški fakulteti. Uvedli smo inovativen ter učinkovit postopek okuževanja sadik zelja s prebadanjem listov s pripomočkom kenzani (Tortosa in sod., 2019). V raziskavo smo vključili 7 slovenskih hibridov zelja, dve rasi Xcc: rasa 1, rasa 4, ter za Slovenijo avtohtoni izolat Xcc CZ06, ki še ni genotipiziran (Kmetijski inštitut Slovenije). Xcc smo 48 ur gojili na LB ploščah pri temperaturi 27 °C. Kolonije smo resuspendirali v sterilni vodi in redčili na 10^8 CFU/ml. Z nastalo bakterijsko suspenzijo smo s prebadanjem lista dvomesečnih sadik zelja okužili naslednje, že potrjene hibride: Presnik, Kosobrin, Kisolin, Krpan in tri hibride v postopku potrjevanja: Brincelj, Vitranc in križanec 79 x 304. Za vsako okuževanje smo pripravili 5 bioloških ponovitev, skupno 140 sadik. Simptome Xcc smo ocenjevali po lestvici 1–5 (Lu in sod., 2023) po tednu oziroma po dveh tednih od okuževanja ter jih statistično ovrednotili s Studentovim t-testom. Po tednu dni od okuževanja se je kot najbolj toleranten hibrid izkazal Kisolin, ki je pri vseh treh genotipih Xcc izkazoval najbolj blage simptome okužbe. Sledita mu Vitranc, ki kaže predvsem toleranco na Xcc rasa 1, in Kosobrin s toleranco na Xcc rasa 4. Med testiranimi hibridi nismo odkrili takega, ki bi izkazoval odpornost na Xcc. Okužene dele lista smo vzorčili, homogenizirali v tekočem dušiku in shranili na – 80 °C. V prihodnjih mesecih bomo iz rastlinskega materiala s CTAB postopkom izolirali DNA in jo uporabili za kvantitativno določanje Xcc s qPCR. Podatek o količini Xcc v rastlini bomo primerjali z ocenjenimi simptomi in s tem pokazali na potencial hibridov Kisolin, Vitranc in Kosobrin. Na podlagi ugotovitev bomo v prihodnje opravili nadaljnje raziskave z manjšim inokulom in v daljšem časovnem obdobju ter tako bolje ovrednotili interakcije med proučevanimi hibridi in Xcc. V tej raziskavi smo razvili učinkovit sistem okuževanja sadik zelja z Xcc. Ta pristop omogoča natančno in hitro preverjanje odpornosti hibridov že v zgodnjih razvojnih fazah, kar lahko pospeši proces selekcije in žlahtnjenja. Gojenje tolerantnih oziroma odpornih sort je namreč ključna in trajnostna strategija za obvladovanje črne žilavke kapusnic.

Ključne besede: hibrid, zelje, črna žilavka

[20] Mag. biotehnol., Biotehniška fakulteta, Oddelek za agronomijo, e-pošta: primoz.fabjan@bf.uni-lj.si
[21] Doc. dr., Biotehniška fakulteta, Oddelek za agronomijo, e-pošta: katarina.rudolf.pilih@bf.uni-lj.si

Investigation of the susceptibility of Slovenian cabbage hybrids (*Brassica oleracea* var. *capitata* L.) to infection with black rot of crucifers (*Xanthomonas campestris* pv. *campestris*)

The bacterium *Xanthomonas campestris* pv. *campestris* (Xcc) causes black rot of cabbage and other cruciferous plants. The disease is characterized by a V-shaped yellowing of the leaf edges, a typical blackening of the leaf veins and later also a blackening of the middle of the head. Affected cabbage is unsuitable for sale or processing. As part of the public service (PSH), hybrid varieties are bred using both traditional and biotechnological methods. This includes the development of pure lines, testing of combining ability and selection of the best hybrids. In this abstract, we present a pilot study conducted at the Biotechnical faculty to establish an effective protocol for determining the resistance of cabbage hybrids to Xcc. We have introduced an innovative and effective method for the inoculating cabbage seedlings by pricking the leaves with a Kenzani tool (Tortosa et al., 2019). We included 7 Slovenian cabbage hybrids and 3 strains of Xcc: race 1, race 4 and the Slovenian isolate CZ06, which has not yet been genotyped (Agricultural Institute of Slovenia). Xcc was grown on LB plates at 27 °C for 48 hours. . Colonies were resuspended in sterile water and diluted to 10^8 CFU/ml. The bacterial suspension was used to inoculate 2-month-old cabbage seedlings by pricking the leaves. The following hybrids were tested: Presnik, Kosobrin, Kisolin, Krpan and three hybrids that are still under control: Brincelj, Vitranc, and hybrid 79 x 304. For each inoculation, 5 biological replications were prepared, for a total of 140 seedlings. Symptoms of Xcc infection were scored on a 1-5 scale (Lu et al., 2023) one and two-weeks after inoculation and statistically analyzed using the Student's t-test. One week after inoculation, the most tolerant hybrid was Kisolin, which showed the mildest symptoms of infection with all three Xcc genotypes. It was followed by Vitranc, which showed tolerance primarily to Xcc race 1, and Kosobrin, which demonstrated tolerance to Xcc race 4. No hybrid tested exhibited resistance to Xcc. Infected leaf samples were collected, homogenized in liquid nitrogen, and stored at – 80 °C. In the coming months, we plan to isolate DNA from the plant material using the CTAB method and perform quantitative determination of Xcc via qPCR. The amount of Xcc in the plant will be compared with the observed symptoms to assess the potential of hybrids such as Kisolin, Vitranc, and Kosobrin. Based on the findings, we will conduct further research using a smaller inoculum and over a longer period to better evaluate interactions between the studied hybrids and Xcc. This approach allows accurate and rapid screening of hybrid resistance at early stages of development, speeding up the selection and breeding process. Breeding tolerant or resistant varieties is an important and sustainable strategy against black rot.

Keywords: hybrid, cabbage, black rot

Pridelava zelišč v Sloveniji – kje smo?

Barbara ČEH[22], Alenka BARUCA ARBAJTER, Matjaž HLADNIK, Nataša FERANT, Monika OSET LUSKAR in Dunja BANDELJ

Površine, namenjene pridelavi zelišč, so v večini slovenskih regij majhne. Izstopa le Pomurska regija, kjer je leta 2022 pridelava zelišč obsegala 118 hektarjev, kar predstavlja 63 % vseh površin z zelišči v državi. Površina z zelišči se sicer v skupnem merilu z leti povečuje. Največja površina pod zelišči je bila med letoma 2011 in 2022 po podatkih SURS leta 2021, in sicer 190 ha. Število kmetijskih gospodarstev (KMG), ki se ukvarjajo s pridelavo zelišč, je bilo največje leta 2022, in sicer 300 (296 na prostem, štirje v zaprtem prostoru). Posamezno KMG je v letu 2011 pridelovalo zelišča na povprečno 0,34 ha, v letu 2022 na 0,5 ha. V Pomurski regiji imajo največjo povprečno površino pod zelišči na KMG, to je 2,26 ha, Gorenjska regija ima povprečno površino na KMG podobno slovenskemu povprečju, vse ostale regije pa manjšo. V Pomurski, Savinjski in Posavski regiji se z leti povečuje tudi število pridelovalcev zelišč.
Z anketo, ki smo jo osebno izvedli med 78 pridelovalci zelišč v Sloveniji, kar predstavlja 35 % vseh registriranih pridelovalcev zelišč (po podatkih MKGP je bilo leta 2022 v register vpisanih 223 pridelovalcev zelišč), smo želeli ugotoviti, na kakšni površini pridelujejo zelišča, koliko kmetijskih gospodarstev se ukvarja s pridelavo zelišč in katera zelišča pridelujejo. Rezultati ankete kažejo, da 35 % anketiranih pridelovalcev zelišča prideluje na skupno 80 ha, kar je več, kot bi pričakovali glede na podatke iz zbirnih vlog. Na 78 anketiranih kmetijah pridelujejo več kot 100 različnih vrst zelišč, vendar je le 23 vrst posajenih na skupaj več kot 10 arov in predstavljajo 99 % skupne površine pod zelišči vseh anketiranih KMG. Pridelavo treh zelišč (sivka, meta in melisa) so navedli pridelovalci skoraj v vseh regijah, druga zelišča se pojavljajo v manj regijah. Na kar 67 % skupne površine je eno zelišče (pegasti badelj), ki se prideluje (je bilo poročano) le v eni regiji (Pomurska). Destilacija je najpogostejši in najobsežnejši način predelave, na kmetijah pa imajo še zelo pester nabor izdelkov, kot je razvidno iz besednega oblaka. Trženje je prepuščeno iznajdljivosti posameznikov (prodaja na tržnicah, na domu …), pristopi k prodaji so med kmetijami zelo različni, vsi pa pogrešajo skupni odkupni center.

Ključne besede: zelišča, pridelava glede na regijo, površina, pridelek, izdelki iz zelišč

Zahvala. Prispevek je nastal v okviru CRP V4-2207 Možnosti razvoja zeliščarstva v Sloveniji, ki sta ga financirala Javna agencija za znanstvenoraziskovalno in inovacijsko dejavnost Republike Slovenije in Ministrstvo za kmetijstvo, gozdarstvo in prehrano RS.

Besedni oblak s predstavitvijo izdelkov iz zelišč, ki jih izdelujejo na 78 anketiranih kmetijah.
A word cloud featuring the presentation of herbal products made on 78 surveyed farms.

[22] Dr., Inštitut za hmeljarstvo in pivovarstvo Slovenije, e-pošta: barbara.ceh@ihps.si

Herb cultivation in Slovenia – where are we?

The areas designated for herb cultivation are small in most Slovenian regions. The Pomurska region stands out, where in 2022, herb cultivation covered 118 hectares, representing 63% of all herb-growing areas in the country. Overall, the area dedicated to herbs has been increasing over the years. The largest area under herb cultivation between 2011 and 2022, according to the Statistical Office of the Republic of Slovenia, was recorded in 2021, amounting to 190 hectares. The number of agricultural holdings (AH) involved in herb cultivation was the highest in 2022, with 300 (296 in open fields and four in enclosed spaces). In 2011, an individual AH in Slovenia cultivated herbs on an average of 0.34 hectares, which increased to 0.5 hectares in 2022. In the Pomurska region, the average area under herbs per AH is the largest, at 2.26 hectares. The Gorenjska region's average area per AH is similar to the Slovenian average, while all other regions have smaller averages. In the Pomurska, Savinjska, and Posavska regions, the number of herb growers has also been increasing over the years.

Through a survey conducted personally among 78 herb growers in Slovenia, representing 35% of all registered herb growers (according to the Ministry of Agriculture, Forestry, and Food, 223 herb growers were registered in 2022), we aimed to determine the area used for herb cultivation, the number of agricultural holdings involved, and the types of herbs grown.

The survey results indicate that 35% of the respondents cultivate herbs on a total of 80 hectares, which is more than expected based on data from consolidated applications. The 78 surveyed farms grow over 100 different herb species, but only 23 species are cultivated on more than 1000 m^2 collectively; at the same time, the sum of area under these 23 herbs accounts for 99% of the total herb cultivation area among the surveyed agricultural holdings.

The cultivation of three herbs was reported by growers in almost all regions, while other herbs are grown in fewer regions. Interestingly, a single herb occupies 67% of the total cultivation area in Slovenia, and it is reported to be grown in just one region, Pomurska.

Distillation is the most common and widespread processing method, though farms also produce a diverse range of products, as illustrated in the generated word cloud.

Marketing strategies largely rely on individual ingenuity, including sales at markets, on the farm, and through direct channels. However, all respondents expressed a desire for a centralized purchasing centre to streamline sales and enhance profitability.

Keywords: herbs, cultivation by region, area, yield, herb-based products

Acknowledgment: This contribution was created as part of the CRP V4-2207 project *Opportunities for the Development of Herb Cultivation in Slovenia*, funded by the Slovenian Research and Innovation Agency and the Ministry of Agriculture, Forestry, and Food of the Republic of Slovenia.

Pridelava zelišč na večjih površinah – priložnost za dodaten dohodek na kmetiji

Barbara ČEH[23], Vesna MIHALIČ, Nataša FERANT in Monika OSET LUSKAR

V Sloveniji se zelišča pridelujejo na številnih kmetijah, vendar na manjših površinah in večinoma za lastne potrebe. Z namenom, da prenesemo znanje o pridelavi zelišč z manjših površin na večje površine z večinoma mehanizirano pridelavo, smo izvedli poskusno pridelavo zelišč na različnih zastirkah in brez uporabe le te na večji hmeljarski kmetiji na Gomilskem. Na razdaljo, ki je omogočala mehansko zatiranje plevelov (okopavanje) na parceli brez zastirke smo posadili citronko, meliso, jabolčno meto, slez in komarček. Primerjali smo tri zastirke (črn polprepusten agrotekstil, miskantus in kokosova vlakna) s kontrolo (brez zastirke). Merili smo velikost pridelka, izračunali stroške zasnove nasada ter stroške pridelave. Kalkulacije za prvoletne nasade smo izdelali po modelu kalkulacije stroškov pridelave zelišč (STRO-ZEL_01), ki je prosto dostopen na spletni strani: CRP V4-2207 Možnosti razvoja zeliščarstva v Sloveniji - Inštitut za hmeljarstvo in pivovarstvo Slovenije.
Največji pridelek droge smo dobili na agrotekstilu (15 kg/ar suhe snovi citronke, 29 kg/ar melise, 18 kg/ar jabolčne mete in 18 kg/ar sleza; glejte graf), sledil je pridelek na kokosovih vlaknih in miskantusu, najmanjši je bil na kontrolni parceli brez zastirke.

Preglednica 1: Ocena stroškov pri pridelavi zelišč v prvem letu pri različnih zastirkah / Table 1: Cost estimation for herb cultivation in the first year under different mulches

Zastirka / Mulch	Ocena stroškov zastirke / Mulch cost estimation (EUR /ar)	Ocena stroška naprave nasada / Estimation of plantation establishment costs (EUR /ar)	Ocena stroška dela / Labor cost estimation (EUR /ar)
Agrotekstil / Agrotextile	199	693	50
Kokosova vlakna / Coconut Fibers	99	620	350
Miskantus / Miscanthus	137	660	290
Kontrola / Control without mulch	0	512	310

Vse zastirke so ugodno vplivale na rast in pridelek, saj so segrevale tla in zmanjševale evapotranspiracijo. Agrotekstil, je poleg tega še odlično dušil plevel, ki je bil v deževni in topli sezoni 2024 velik problem v ekološki pridelavi in tudi sicer. Ostale zastirke plevela niso zadušile, zato je bilo potrebno kljub dodatnim stroškom še vedno izvajati pletje, obenem se je kokosova zastirka zatikala v kosilnico in oteževala spravilo, s čimer se je obseg dela in stroškov na kmetiji zelo povečal. Poraba delovnih ur je bila pri agrotekstilu najmanjša (preglednica 1), potrebna je bila le manjša pletev okrog zelišč v luknjah agrotekstila, kjer so se razrastli pleveli. V oceno stroškov dela smo vključili tudi dvakratno spravilo pridelka. Če vhodni strošek primerjamo z vrednostjo ročnih in strojnih ur, potrebnih za pridelavo zelišč na drugih zastirkah in pri kontroli brez zastirke, se strošek agrotekstila povrne že v prvem oz. drugem letu pridelave zelišč. Na kmetiji so tudi ugotovili, da so za njihove razmere bolj primerna nižja zelišča (melisa, jabolčna meta in citronka), saj sta bili zelišči, ki zrasteta višje (slez, komarček), občutljivi na veter (poleganje) in tudi na okopavanje s traktorskim okopalnikom.

Ključne besede: zelišča, pridelek, kalkulacija stroškov pridelave, zastirke
Zahvala. Prispevek je nastal v sklopu pilotnega projekta Povezovalno trženjski center za zelišča, ki je potekal pod okriljem ukrepa 16.2 Podpora za pilotne projekte ter za razvoj novih proizvodov, praks, procesov in tehnologij.

[23] Dr. Inštitut za hmeljarstvo in pivovarstvo Slovenije, e-pošta: barbara.ceh@ihps.si

Herb cultivation on larger areas – an opportunity for additional farm income

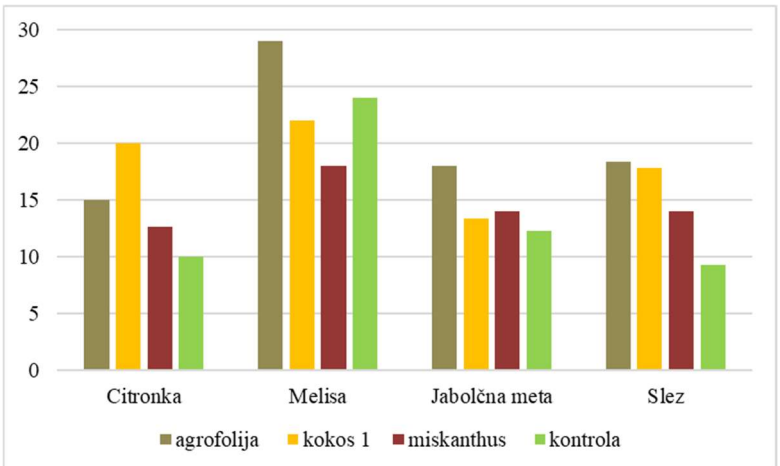
Herbs are cultivated on many farms in Slovenia, typically on smaller areas and mostly for personal use. With the aim of transferring knowledge about herb cultivation from smaller to larger areas, primarily mechanized cultivation, we conducted experimental herb cultivation on different mulches and without using mulch on a larger hop-growing farm in Gomilsko. At a distance that allowed mechanical weed control (hoeing) on plots without mulch, we planted lemongrass, lemon balm, apple mint, marshmallow, and fennel. We compared three types of mulch (black semi-permeable agrotextile, miscanthus, and coconut fibres) with a control (no mulch). We measured yield, calculated establishment costs, and production costs. The calculations for first-year plantings were made based on the cost calculation model for herb cultivation (STRO-ZEL_01), which is freely available on the website: CRP V4-2207 Možnosti razvoja zeliščarstva v Sloveniji - Inštitut za hmeljarstvo in pivovarstvo Slovenije.

The highest yield of dry matter was obtained on agrotextile (15 kg/ha of dry matter from lemongrass, 29 kg/ha from lemon balm, 18 kg/ha from apple mint, and 18 kg/ha from marshmallow; see Figure below). The yield followed on coconut fibres and miscanthus, while the lowest yield was observed on the control plot without mulch.

All mulches had a favourable effect on growth and yield, as they warmed the soil and reduced evapotranspiration. Agrotextile, in addition, effectively suppressed weeds, which were a significant issue in the rainy and warm season of 2024 in organic cultivation and beyond. The other mulches did not effectively suppress weeds, requiring additional weeding despite their costs. Coconut mulch also got caught in the mower, complicating harvesting, which greatly increased labour efforts and costs on the farm. As a result, labour hours were lowest with agrotextile (see Table 1), requiring only minor weeding around herbs in the holes of the agrotextile where weeds could grow. In the labour cost assessment, we included twice the harvest of the yield. Comparing the input cost with the value of manual and machine hours needed for herb cultivation under other mulches and without mulch (control), the cost of agrotextile was recovered in the first or second year of herb cultivation.

Besides that, the farm determined that lower-growing herbs (lemon balm, apple mint, and lemongrass) were more suitable for their conditions, as taller herbs (marshmallow, fennel) were sensitive to wind (lodging) and tractor hoeing.

Keywords: herbs, yield, cost calculation, mulches.



Pridelek suhe snovi zelišč (kg/ar) pri različnih zastirkah (kontrola = brez zastirke)

Yield of dry matter of herbs (kg/ha) under different mulches (Control = without mulch)

Možnost pridelave kurkume (*Curcuma longa* L.) v Sloveniji

Tamara KOROŠEC[24], Miša PUŠENJAK, Igor ŠKERBOT, Barbara ČEH in Mojca HRIBERNIK

Pridelava kurkume (*Curcuma longa* L.) prvenstveno poteka v tropskih in subtropskih predelih sveta, zlasti v Aziji, kjer je največja proizvajalka, porabnica in izvoznica te začimbnice Indija. Večina pridelka rizomov kurkume se predela v državah tretjega sveta in distribuira na velike razdalje, saj so sušeni rizomi vir naravnih pigmentov in bioaktivnih snovi za kozmetično, prehransko, tekstilno in farmacevtsko industrijo širom po svetu. Z željo po zmanjšanju ogljičnega odtisa, ki je posledica globalne trgovine, se povečuje interes, hkrati s podnebnimi spremembami pa se pojavljajo možnosti za pridelavo te rastline v zmernem podnebnem pasu. V Sloveniji tržne pridelave kurkume nimamo, zato smo na treh kmetijah in IHPS pilotno preizkusili možnosti pridelave v plastenjaku z mikrorazpršilci (KMG 1), v plastenjaku s kapljičnim namakanjem (KMG 2), v plastenjaku z zalivanjem (KMG 3), v odprtem tunelu (IHPS), na prostem v dvignjeni gredi (KMG 3), v loncih v rastlinjaku (IHPS) in loncih na prostem (KMG 3). Gnojenje je bilo na vseh kmetijah izvedeno glede na analizo tal in gnojilni načrt. Sadike so bile vzgojene v italijanskem podjetju Cooperazione agricola Braccianti Giulio Bellini in dobavljene v velikosti 15–20 cm. Sadike so bile testirane na prisotnost karantenske bakterije *Ralstonia Solanacearum* na NIB. Izvidi testiranj so bili negativni. Z dobavo sadik smo prihranili čas kaljenja rizomov in se izognili izpadu pridelka zaradi morebitnih težav pri kalivosti. Sajenje je potekalo od 19. aprila do konca maja v odvisnosti od vremenskih razmer, temperature tal in dorečenega načina pridelave za posamezno kmetijo. Sadike smo sadili v tla, ogreta na 20 °C. Pridelke smo vzorčili po prvi močni ohladitvi konec septembra 2024, na vsako obravnavanje po 12 rastlin na en termin vzorčenja, vzorčenja smo ponavljali na 14 dni (2-krat ali 3-krat). V preizkušanju nas je prvenstveno zanimal pridelek svežih rizomov, ki so tržni del rastline. Največji pridelek svežih rizomov na rastlino smo stehtali na KMG 1 v povprečju 1106 g, sledi KMG 2 s 733 g, IHPS (odprti tunel) s 514 g, KMG 3 (plastenjak) s 392 g, IHPS (lonci znotraj) s 333 g, KMG 3 (lonci zunaj) s 297 g in KMG 3 (dvignjena greda na prostem) s 288 g. Glede na opazovanja in meritve lahko ugotovimo, da je najboljše pogoje mogoče ustvariti v rastlinjaku/plastenjaku z večjim volumnom zraka in z uporabo mikrorazpršilcev, s katerimi zagotavljamo visoko zračno vlažnost. Masa rizomov, pridelanih v plastenjakih, je bila v najtesnejši korelaciji z maso zelenega dela rastline (0,83), največji indeks mase svežih rizomov glede na maso zelenega dela smo zaznali pri pridelavi v loncih in pridelavi v tunelu (1,8 in 2,0), kjer so tudi rastline z malo zelene mase, dale relativno dobre pridelke. Korelacija med višino rastlin in maso rizomov je bila 0,70, medtem kot so bile korelacije med številom listom in maso rizomov ter številom stranskih poganjkov in maso rizomov nizke. Značilno več stranskih poganjkov so naredile rastline, ki so rasle na prostem ali v odprtem tunelu. Povprečno so bili primarni rizomi najdaljši pri pridelavi v loncih v rastlinjaku (8,4 cm), medtem ko se je pri drugih načinih pridelave gibala od 4 cm (lonci in dvignjena greda na prostem) do 5,97 cm (plastenjak na KMG 1). Prvi preliminarni rezultati kažejo, da lahko v primerjavi s pridelavo na prostem v deželah tretjega sveta, pri nas v odprtih tunelih pridelamo primerljive, v plastenjakih pa nadpovprečne količine rizomov kurkume.

Ključne besede: kurkuma, *Curcuma longa*, pridelava
Zahvala. Projekt je bil financiran s strani Evropske unije in Ministrstva za kmetijstvo, gozdarstvo in prehrano Republike Slovenije (MKGP).

[24] Dr., Kmetijsko gozdarski zavod Maribor, e-pošta: tamara.korosec@kmetijski-zavod.si

The potential for turmeric (*Curcuma longa* L.) cultivation in Slovenia

The cultivation of turmeric (*Curcuma longa* L.) predominantly occurs in tropical and subtropical regions, primarily in Asia, with India being the largest producer, consumer, and exporter of this spice. Most turmeric rhizomes are produced in developing countries and distributed globally, serving as a source of natural pigments and bioactive compounds for the cosmetic, food, textile, and pharmaceutical industries across the globe. To mitigate the impact of globalization and reduce the carbon footprint, interest in cultivating turmeric in temperate climates is increasing. Furthermore, climate change increases the possibility of cultivation. In Slovenia, there is no commercial turmeric production. Therefore, pilot cultivation trials were conducted at three farms and at the Institute of Hops and Brewing of Slovenia (IHPS). These trials explored various cultivation methods: in plastic greenhouse with micro-sprinklers (Farm 1), plastic greenhouse with drip irrigation (Farm 2), plastic greenhouse with watering (Farm 3), open tunnel (IHPS), outdoor raised bed (Farm 3), pots in greenhouse (IHPS), and pots outdoors (Farm 3). Fertilization was based on soil analysis and fertilization plans. The planting material, originating from the Italian company Cooperazione Agricola Braccianti Giulio Bellini, consisted of seedlings 15–20 cm in size. These seedlings were tested for the quarantine bacterium *Ralstonia solanacearum* at the National Institute of Biology, with negative results. Using seedlings avoided germination delays and potential crop losses due to germination issues. Planting occurred from April 19 to late May, depending on weather conditions, soil temperature, and the cultivation method chosen for each site. The seedlings were planted in soil warmed to 20°C. Harvesting began after the first significant cold spell in late September, with 12 plants sampled per treatment at 14-day intervals (2–3 times). The primary focus was the yield of fresh rhizomes, the marketable part of the plant. The highest average rhizome yield was recorded at Farm 1 (1106 g), followed by Farm 2 (733 g), IHPS in a tunnel (514 g), Farm 3 in a greenhouse (392 g), IHPS in pots indoors (333 g), Farm 3 in pots outdoors (297 g), and Farm 3 in outdoor raised beds (288 g). Observations indicate that the best conditions can be created in greenhouses with higher air volume and micro-sprinklers to maintain high humidity. Rhizome mass was in the closest correlation with the green mass of the plant (0.83). The highest rhizome mass-to-green mass index was measured in pots and tunnel (1.8 and 2.0), where plants produced relatively good yields despite limited green mass. The correlation between plant height and rhizome mass was 0.70, while correlations between leaf number and rhizome mass, as well as side shoots and rhizome mass, were low. Plants grown outdoors or in open tunnel developed significantly more side shoots than plants in the greenhouses or pots. The longest primary rhizomes were measured in pots in the greenhouse (8.4 cm), while in other treatments the length ranged from 4 cm (pots and raised beds outdoors) to 5.97 cm (Farm 1 greenhouse). Preliminary results indicate that turmeric cultivated in open tunnels in Slovenia can achieve rhizome yields comparable to those of outdoor cultivation in tropical regions. In contrast, greenhouse cultivation can produce above-average rhizome yields.

Keywords: turmeric, *Curcuma longa*, cultivation

Acknowledgments: The project was funded by the European Union and the Ministry of Agriculture, Forestry, and Food of the Republic of Slovenia (MKGP).

Vpliv mikroplastike na kalivost semen bele gorjušice (*Sinapis alba* L.)

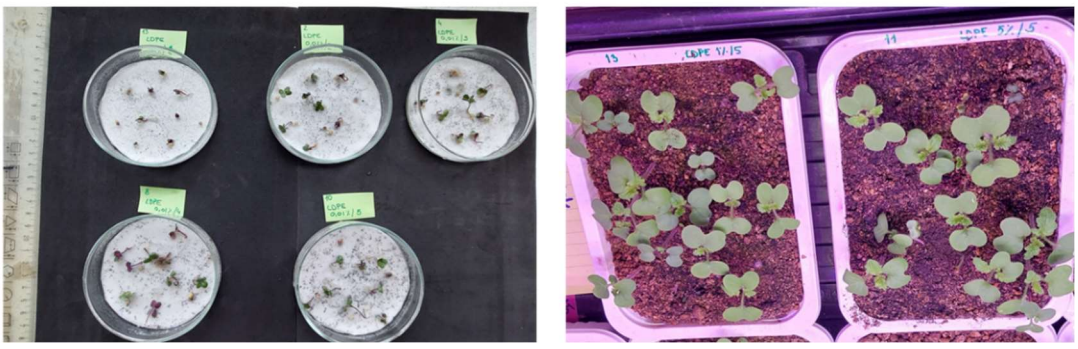
Špela ŽELEZNIKAR[25], Dara BAVDEK in Nina KACJAN MARŠIĆ

Raziskava se osredotoča na vpliv delcev mikroplastike (MP) polietilena nizke gostote (LDPE) na kaljenje semen bele gorjušice (*Sinapis alba* L.). Vse pogostejša uporaba plastike vpliva na njeno kopičenje v okolju, kjer se sčasoma preko procesov razgradnje pretvarja v MP. Ta poleg onesnaževanja kopenskih ekosistemov vpliva tudi na različne naravne procese, med njimi tudi na kalitev različnih rastlinskih vrst. V kmetijstvu so plastične zastirke iz LDPE glavni vir MP v tleh. S porastom uporabe zastirnih tehnik narašča tudi zanimanje za raziskave vpliva MP na procese v kmetijstvu.
V raziskavi smo najprej preučevali splošni vpliv MP na kalitev bele gorjušice kot modelne rastline (Slika 1A), kasneje pa smo raziskavo razširili na spremljanje vpliva MP na rast rastlin do faze kalic (Slika 1B). MP, izdelana iz LDPE – najpogostejšega materiala, ki sestavlja plastične zastirke – je bila pripravljena s procesom mletja. Raziskava je bila razdeljena na laboratorijski in lončni poskus. V laboratorijskem poskusu smo med kalitvijo semen na petrijevkah opazovali vpliv MP na uspešnost kalitve in dolžino kalčka, medtem ko smo v lončnem poskusu s semeni, posejanimi v izbrani substrat, spremljali dolžino korenin in višino nadzemnega dela rastline. Oba poskusa sta bila izvedena v kontroliranih rastnih razmerah. Rezultati kažejo, da nizka koncentracija MP (0,01% w/w) pozitivno, visoka koncentracija (1% w/w) MP pa negativno vpliva na uspešnost kalitve. Prisotnost velikih koncentracij MP v substratu nakazuje na fizično mašenje por semenske ovojnice in koreninske kapice, kar ovira absorpcijo vode in hranil iz okolja. To negativno vpliva na proces kalitve in nadaljnjo rast rastlin. Na podlagi teh ugotovitev sklepamo, da fizični vpliv MP na rastline lahko vodi k zmanjšanju pridelka na kmetijskih površinah, onesnaženih s MP.

Ključne besede: mikroplastika, bela gorjušica, kalitev, polietilen nizke gostote (LDPE)

Zahvala. Raziskava je bila podprta s pomočjo projekta MINAGRIS (H2020, št. 101000407).

A B



Kalitev semen bele gorjušice v laboratoriju (A) ter spremljanje rasti bele gorjušice v lončnem poskusu (B).
Germination of white mustard seeds in the laboratory (A) and monitoring the growth of white mustard in a pot experiment (B).

[25] Biotehniška fakulteta, Oddelek za agronomijo, e-pošta: spela.zeleznikar@bf.uni-lj.si

Effect of microplastics on seed germination of white mustard *(Sinapis alba* L.*)*

The research focuses on the impact of low-density polyethylene (LDPE) microplastic (MP) particles on the germination of white mustard (*Sinapis alba* L.) seeds. The increasing use of plastic by humans contributes to its accumulation in the environment, where, through degradation processes, it gradually breaks down into MP. In addition to polluting terrestrial ecosystems, MP affects various natural processes, including the germination of different plant species. In agriculture, LDPE plastic mulches are a primary source of MP in the soil. As the use of mulching techniques grows, so does the interest in studying the effects of MP on agricultural processes.
Initially, the study examined the general effect of MP on the germination of white mustard as a model plant (Figure 1A). Later, the research was expanded to monitor the effect of MP on plant growth (Figure 1B). The MP, made from LDPE – the most common material used in plastic mulches – was prepared through a grinding process. The research was divided into two parts: a laboratory and a pot experiment. In the laboratory experiment, we monitored the impact of MP on germination success and seedling length by germinating seeds in Petri dishes. In the pot experiment, where seeds were sown in a selected substrate, we also monitored root length and plant height. Both experiments were conducted under controlled growth conditions. The results indicate that low concentration (0,01% w/w) of MP have a positive effect on germination success, while high concentration (1% w/w) has a negative effect. The presence of high concentration of MP in the substrate suggests that MP physically clogs the pores of the seed coat and root cap, hindering water and nutrient absorption from the environment. This negatively affects the germination process and the subsequent growth of plants. Based on these findings, we conclude that the physical impact of MP on plants may lead to reduced yields in agricultural fields contaminated with MP.

Keywords: microplastic, white mustard, germination, low density polyethylene (LDPE

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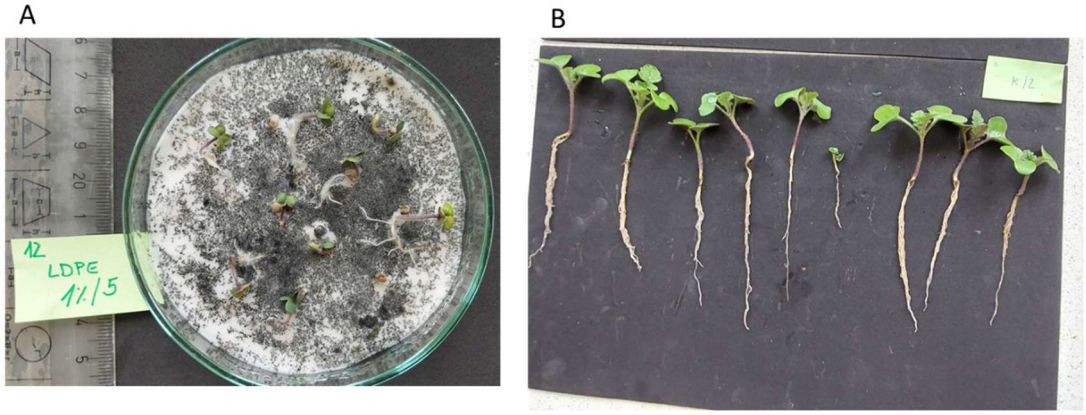


Germinating seeds in Petri dishes at the end of the experiment (A) and white mustard plants at the end of the pot experiment (B).

Kalitev semen v petrijevkah ob koncu laboratorijskega poskusa (A) in rastline bele gorjušice ob koncu lončnega poskusa (B).

Vpliv rastnih razmer na obliko gomoljev sorte Kresnik

Peter DOLNIČAR[26], Uroš BENEC in Barbara PIPAN

Kresnik je slovenska sorta krompirja, vzgojena na Kmetijskem inštitutu Slovenije leta 1989. Gomolji so dolgi, pogosto nepravilnih oblik in na bazalnem delu običajno zaviti. V prodajni sezoni 2023/2024 so dobavitelji dali na trg semenski krompir sorte Kresnik nizozemskega izvora, pri katerem so bili gomolji večinoma okrogle do ovalne oblike, medtem ko so gomolji iz semenske pridelave v Sloveniji popolnoma ustrezali uradnemu opisu sorte. To je v postopku certifikacije vzbudilo dvome o sortni pristnosti semenskega materiala iz Nizozemske, pojavljali pa so se tudi dvomi kupcev. Na trgu smo odvzeli vzorce gomoljev obeh izvorov ter na njih izvedli temeljit vizualni pregled gomoljev po CPVO (CPVO-TP/023/3 (15/03/2017)) in UPOV (UPOV-TG/23/7 (25/10/2022)) deskriptorih. Ocenjevali smo barvo in obliko gomoljev, barvo mesa in 11 lastnosti svetlobnih kaličev, ki so značilne za posamezno sorto in pomemben del identifikacije sort po UPOV. Gomolje smo posadili v rastlinjaku na KIS, kjer smo primerjali habitus rastlin in obliko novonastalih gomoljev. Na zelenih delih rastlin smo odvzeli tudi vzorce za genetske analize. Uporabili smo šest vrst specifičnih DNA markerjev (STM lokusi). Na nivoju alelov smo ugotovili popolno identičnost v alelnih profilih za vse obravnavane vzorce obeh skupin/tipov gomoljev na kar štirih lokusih (STM3012, STM1024, STM2028, STM5136), kar kaže na to, da gre pri obeh skupinah za sorto Kresnik. Primerjava alelnih profilov je pokazala, da se na dveh lokusih (STM2022, STM5148) nakazujejo majhne alelne spremembe pri vzorcih, ki izvirajo iz okroglih gomoljev. Povečane so bile frekvence nekaterih redkih alelov v primerjavi z aleli, ki izvirajo iz tipičnih gomoljev. Poudariti je potrebno, da pri tem ne gre za alele, ki bi bili specifični le za rastline, ki izvirajo iz okroglih gomoljev, le frekvenca redkejših alelov je nekoliko višja kot pri standardih (ukrivljenih) gomoljih. Že po vizualnem pregledu svetlobnih kaličev pri vzgojenih rastlinah v rastlinjaku, še posebej pa na gomoljih po izkopu, se je izkazalo, da so gomolji iz obeh virov vizualno identični in torej gre za sorto Kresnik, kar kažejo tudi rezultati genske analize. Znano je, da interakcija med genotipom in okoljem lahko močno vpliva na morfologijo gomoljev, pri čemer na končne značilnosti, kot sta oblika in globina očes, vplivajo dejavniki, kot so tip tal, temperatura in vlaga. Doslej smo razlike v obliki gomoljev večkrat videli v praksi pri preskušanju sort in pri žlahtnjenju krompirja, vendar razlike nikoli niso bile tako velike, da bi prišlo do popolne spremembe oblike gomoljev iz dolge ledvičaste v ovalno do skoraj okroglo. Razlago za to lahko iščemo v načinu razvoja gomoljev, kjer v prvem obdobju po zasnovi gomoljev pride do hitrega deljenja celic, temu sledi faza vzdolžne rasti celic in na koncu večanje (debelitev) celic ob polnjenju škroba. Verjetno je pri pridelovanju sorte Kresnik na Nizozemskem prišlo do stresa (kakšnega lahko le ugibamo) prav v fazi rasti celic v dolžino, kar je povzročilo skoraj okroglo obliko gomoljev, ki pa se nato ni prenesla na potomstvo. Rezultati kažejo, da so morfološke lastnosti krompirja močno odvisne od okoljskih dejavnikov, kar je treba upoštevati pri certifikaciji semenskega krompirja, preskušanju sort ter žlahtnjenju novih sort krompirja.

Ključne besede: sortna pristnost, oblika gomoljev, DNA markerji, alelni profili

Ledvičasta oblika gomoljev sorte Kresnik / Kidney-shaped form of tubers of Kresnik

[26] Dr., Kmetijski inštitut Slovenije, e-pošta: peter.dolnicar@kis.si

Effect of growing conditions on the shape of the tubers of the variety Kresnik

Kresnik is a Slovenian potato variety bred at the Agricultural Institute of Slovenia (KIS) in 1989. The tubers are long, often irregularly shaped and usually curved at the columnar part. In the 2023/2024 marketing season, suppliers placed on the market seed of the variety Kresnik of the Dutch seed origin with tubers that were mostly round to oval shape, whereas the tubers from the Slovenian origin corresponded perfectly to the official description of the variety. This raised doubts in the certification process as to the varietal authenticity of the seed material from the Netherlands and buyers also raised doubts. Samples of tubers from both origins were taken from the market and subjected to a thorough visual inspection of the tubers based on CPVO (CPVO-TP/023/3 (15/03/2017)) and UPOV (UPOV-TG/23/7 (25/10/2022)) descriptors. Evaluated traits were the colour and shape of tubers, flesh colour and 11 light germ traits, which are cultivar-specific and an important part of UPOV cultivar identification. Tubers were planted in the greenhouse at KIS, where the plant habit and the shape of the newly formed tubers were compared. Samples were also taken from the green parts of the plants for genetic analysis. 6 species-specific DNA markers (STM loci) were used. At the allele level, complete identity in the allele profiles for all the samples of the two groups/types of tubers considered at four loci (STM3012, STM1024, STM2028, STM5136) were found, indicating that both groups are of the variety Kresnik. Comparison of the allele profiles showed that at two loci (STM2022, STM5148) there are slight allelic changes in the samples originating from round tubers in terms of increased frequency of some rare alleles compared to alleles originating from typical tubers. However, it should be stressed that there were no alleles that were specific only to plants derived from round tubers, only that the frequency of the rarer alleles was slightly higher than in the standards (curved tubers). After visual inspection of the light germinated plants grown in the greenhouse, and especially of the tubers after excavation, it appeared that the tubers from both sources are visually identical and that they are of the variety Kresnik, which also corresponds to the results of the genetic analysis. It is known that the interaction between genotype and environment can have a strong influence on the morphology of the tubers, with factors such as soil type, temperature and humidity influencing the final characteristics such as the shape and depth of the eyes. So far, differences in tuber shape have been seen several times in practice in variety trials and in potato breeding, but never to such an extent that the shape of the varieties has changed completely from long kidney-shaped to oval or almost round. This can be explained by the way the tubers develop, where there is a rapid cell division in the first period after the tubers are formed, followed by a phase of longitudinal growth of the cells, and finally an increase in the size (thickening) of the cells as the starch fills in. In the case of the variety Kresnik produced in Netherlands, it is very likely that the stress (we can only guess what it was) occurred during the elongation phase, resulting in an almost round tuber shape which was not passed on to the progeny. The results show that morphological characteristics of potatoes are strongly influenced by environmental factors, which should be considered in seed potato certification, variety trials and breeding of new potato varieties.

Keywords: varietal identity, tuber shape, DNA markers, allelic profiles

Spremenjena oblika gomoljev nizozemskega izvora / Modified form of tubers of Dutch origin

Odziv listnih rež koruze na sušnost ozračja

Kris PIRIH, Marjana ŠUBIC, Klemen ELER, Boris LAZAREVIĆ[27], David LENARČIČ, Boris TURK in Dominik VODNIK[28]

Ob vse pogostejših vročinskih valovih ter ob kroničnem segrevanju planeta se na mnogih geografskih območjih srečujemo z večjo sušnostjo ozračja, t. j. s porastom deficita tlaka vodne pare v atmosferi (*vapor pressure deficit*; VPD). Sušnost ozračja močno vpliva na rast in razvoj rastlin, njen učinek se odraža v zgradbi, morfološko-anatomskih značilnostih in v fizioloških procesih. Za ohranjanje primernega vodnega potenciala in v izogib resnejšim motnjam hidravlične prevodnosti rastline ob porastu VPD pripirajo listne reže. To izboljša učinkovitost rabe vode, a pogosto omejuje fotosintezo, saj je dobava fotosinteznega substrata CO_2 v liste manjša. Posledici sta slabša rast in zmanjšana produktivnost.
V naših študijah smo z uporabo različnih pristopov ocenjevali učinke VPD na listne reže in transpiracijo koruze (*Zea mays* L.). Transpiracijo (E) smo pri različnih vrednostih VPD merili gravimetrično. Z meritvami izmenjave plinov smo na istih rastlinah ovrednotili kinetiko odziva rež na stopenjsko povečevanje VPD. Poleg tega smo odziv rež na dnevne spremembe VPD spremljali tudi v poljskem poskusu, kjer so bile meritve prevodnosti rež (g_s) izvedene v zaporednih dnevih s podobnimi vremenskimi razmerami (dnevnimi spremembami VPD), vendar z različno razpoložljivostjo vode v tleh. V raziskave sta bila vključena dva hibrida koruze (DuPont, Pioneer) z različno odpornostjo na sušo.
Tolerantni hibrid je imel pri meritvah izmenjave plinov nižjo začetno g_s (pri VPD 1 kPa) in zelo občutljiv stomatalni odziv že pri spremembi VPD na 1,5 kPa, medtem ko je bilo najbolj pomembno znižanje g_s pri kontrolnem hibridu pri 1,5 do 2,0 kPa. Transpiracija je bila nižja pri tolerantnem hibridu pri vseh VPD. Meritve na terenu so prav tako pokazale razlike med hibridoma. V suhih tleh je kontrolni hibrid z omejevanjem g_s preprečeval kritičen padec vodnega potenciala, medtem ko je tolerantni hibrid ohranil visoko prevodnost rež. Po večernem namakanju tal je bil zjutraj drugega dne g_s nižji pri tolerantnem hibridu.
Nizek g_s je stalna lastnost tolerantnega hibrida, ki se pojavi tudi v ugodnih razmerah (nizek VPD, vlažna tla). Visoka občutljivost tolerantnega hibrida na rahlo povečanje VPD je skladna s konzervativno strategijo rabe vode. Listne reže se odzivajo na povečanje VPD tudi pri relativno visoki zračni vlagi.

Ključne besede: prevodnost listnih rež, relativna vlažnost, atmosferska suša

Zahvala. Raziskave je podprla Javna agencija za raziskovalno dejavnost RS - program Agroekosistemi (P4-0085) and IC RRC AG (10-0022-0481-001). Avtorji se zahvaljujejo podjetju Corteva Agriscience SLO (g. Robert Matjašec) za semenski material.

[27] Univerza v Zagrebu, Agronomska fakulteta, Oddelek za mineralno prehrano rastlin, Zagreb, Hrvaška, e- pošta: blazarevic@agr.hr
[28] Univerza v Ljubljani, Biotehniška fakulteta, Oddelek za agronomijo, e-pošta: dominik.vodnik@bf.uni-lj.si

Response of maize leaf stomata to atmospheric drought

With the increasing frequency of heat waves and the chronic warming of the planet, many geographical areas are experiencing a greater dryness of the atmosphere, i.e. higher tvapor pressure deficit (VPD). The dryness of the atmosphere has a strong impact on the growth and development of plants, it is reflected in their structure, morphological-anatomical characteristics and physiological processes. In order to maintain an adequate water potential and avoid more serious disturbances in hydraulic conductivity, plants close their leaf stomata when VPD increases. This improves water use efficiency, but often limits photosynthesis as the leaves are supplied with less of the photosynthetic substrate CO_2. The consequences are poorer growth and lower productivity.

In our studies we evaluated the effects of VPD on stomata and transpiration of maize (*Zea mays* L.) using different approaches: i) water loss by transpiration (E) at different VPD values was determined gravimetrically; ii) on the same plants, the kinetics of stomata at stepwise increases in VPD was measured by gas exchange measurements. In addition, the response of stomata to diurnal changes in VPD was followed in a field experiment where stomatal conductivity (g_s) measurements were performed on two consecutive days with similar weather conditions (i.e. diurnal VPD variation) but different soil water availability. Two hybrids with different drought tolerance (DuPont, Pioneer) were tested.

The tolerant hybrid showed a lower initial g_s (at VPD 1 kPa) and a very sensitive stomatal response already at the VPD change to 1.5 kPa, while the most significant decrease in g_s was observed in the non-tolerant hybrid at 1.5 to 2.0 kPa. E was lower in the tolerant hybrid at all VPDs. The field measurements showed a hybrid-dependent response. In dry soil, the control hybrid operated at reduced g_s to prevent a critical drop in water potential, while the tolerant hybrid maintained high g_s. On the morning of the second day (after rewetting the soil), g_s was lower in the tolerant hybrid.

Low g_s is a fixed trait of the tolerant hybrid, occurring even under favourable conditions (low VPD, moist soil). The high sensitivity of the tolerant hybrid to a slight increase in VPD is consistent with a conservative water use strategy. Plant stomata respond to an increase in VPD even at relatively high air humidity.

Keywords: stomatal conductance, relative humidity, atmospheric drought

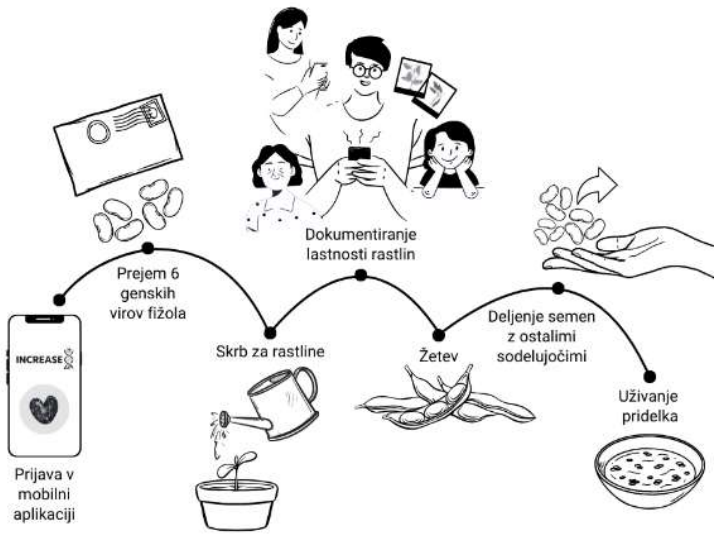
Acknowledgements. The authors acknowledge the financial support of the Slovenian Research Agency - grants Agroecosystems (P4-0085) and IC RRC AG (10-0022-0481-001). We thank Corteva Agriscience SLO (Mr. Robert Matjašec), for seed material

Poskus občanskega raziskovanja znotraj projekta INCREASE

Barbara PIPAN[29], Lovro SINKOVIČ in Vladimir MEGLIČ

V zadnjem času znanstveno raziskovalni projekti v zbiranje in analizo podatkov ter v druga področja raziskovalnega dela vedno bolj vključujejo zainteresirano javnost, kar imenujemo občansko raziskovanje (*angl*. Citizen Science Experiments - CSE). Evropski projekt INCREASE, v katerem poleg Kmetijskega inštituta Slovenije (KIS) sodeluje 25 partnerjev, ima namen ovrednotiti gensko raznolikost ter spodbujati pridelavo in uživanje stročnic v prehrani, med svoje aktivnosti pa vključuje tudi poskus občanskega raziskovanja. Projekt se izvaja po načelih Evropske komisije *„odprta znanost, odprte inovacije in odprt svet"*. V okviru projekta INCREASE je v preskušanju 1.126 linij navadnega fižola, ki jih »občanski raziskovalci« v času rasti spremljajo v različnih pridelovalnih razmerah po Evropi. Konec leta 2024 smo pričeli peto leto (krog) registracij za sodelovanje v poskusu občanskega raziskovanja v 30-ih državah. V zadnjih štirih krogih izvajanja poskusa občanskega raziskovanja je pri preučevanju agrobiodiverzitete navadnega fižola sodelovalo več kot 22.000 občanskih raziskovalcev. Aplikacija INCREASE CSA za pametne telefone je na voljo v 11-ih jezikih in je glavno orodje potrebno za izvajanje registracije, potrjevanja prejetega materiala navadnega fižola in beleženja lastnosti med rastjo. Uporablja različne sklope deskriptorjev navadnega fižola (#6 ali #21 ali #36) te omogoča fotodokumentacijo in izmenjavo semen z drugimi državljani po Evropi v različnih krogih poskusa občanskega raziskovanja. Evropska komisija je projektu INCREASE podelila „veliko nagrado" EU za občansko znanost za leto 2024. Nagrada je priznanje za vpliv in odličnost projekta k oblikovanju pluralne, vključujoče in trajnostne družbe v Evropi ter k napredku znanosti z opolnomočenjem civilne družbe.

Ključne besede: odprta znanost, občansko raziskovanje, genska raznolikost, deskriptorji, fižol



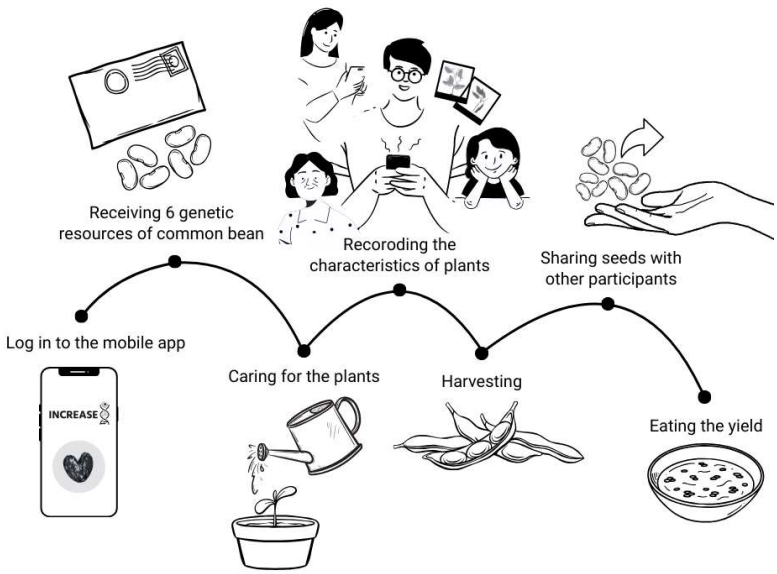
Zahvala. Poskus je financiran s strani Evropske komisije po shemi Obzorja 2020 v sklopu projekta INCREASE, št. pogodbe: 862862 ter s strani Javne Agencije za znanstveno raziskovalno in inovacijsko dejavnost Republike Slovenije (ARIS) preko programske skupine Agrobiodiverziteta (P4-0072). Zahvaljujemo se Špeli Kodre za pripravljen shematski prikaz poteka poskusa o občanskem raziskovanju.

[29] Dr., Kmetijski inštitut Slovenije, e-pošta: barbara.pipan@kis.si

A citizen science research experiment within the INCREASE project

Recently, research projects have increasingly involved the interested public in data collection, analysis and other parts of the scientific process, and such efforts are commonly referred as Citizen Science Experiments (CSE). The European project INCREASE is also an attempt at citizen participation and research, involving 25 partners besides the Slovenian Agricultural Institute (KIS), with the aim of evaluating genetic diversity and promoting the production and consumption of legumes in the human diet. The project is guided by the European Commission's principles of "open science, open innovation and an open world". The INCREASE project has 1.126 common bean landraces in circulation, which are being evaluated by different citizens under different European growing conditions. At the end of 2024, we have started the 5th round of a CSE at European level (30 countries). During the last four rounds (years) of the CSE, more than 22.000 European citizen scientists have been involved in increasing the agrobiodiversity of common bean. The INCREASE CSA smartphone application is available in 11 languages and is the main tool for carrying out the registration, validation of received common bean material, recording of traits through vegetation using different sets of common bean descriptors (#6 or #21 or #36), photo documentation and seed exchange with other citizens across Europe during different rounds of the CSE. The European Commission has awarded INCREASE with the "Grand Prize" for Citizen Science 2024. The prize recognises the impact and excellence of the project in contributing to the creation of a pluralistic, inclusive and sustainable society in Europe and to the advancement of our knowledge through the empowerment of civil society.

Keywords: open science, citizen science, agrobiodiversity, descriptors, common bean



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Inhibitorji proteinaz – vloga in aplikacije v trenutni pridelavi poljščin

Nevena NAGL[30]

Esencialne aminokisline nastanejo z razgradnjo prehranskih beljakovin z encimi, imenovanimi proteinaze. Vloga proteinaz je sproščanje peptidov in aminokislin iz prehranskih beljakovin zato, da bi zadostili prehranskim potrebam organizma. Rastlinojedci (živali in žuželke) absorbirajo vse potrebne beljakovine z uživanjem rastlin. Zato so rastline razvile obrambne mehanizme za zmanjšanje plenjenja in eden od teh mehanizmov je sposobnost, da so nesprejemljiv vir hrane. Rastline proizvajajo številne sekundarne metabolite, vključno z zaviralci proteinaz (PI), ki motijo prebavo beljakovin z zaviranjem aktivnosti proteinaze v črevesju. Pri zaužitju PI inaktivirajo proteinaze v prebavnem traktu, zmanjšajo prebavljivost in adsorpcijo beljakovin, povzročijo hipertrofijo trebušne slinavke in zavirajo rast. Med različnimi razredi rastlinskih proteinaz so serinske in cisteinske proteinaze najbolj prisotne v prebavnih sistemih gospodarsko pomembnih razredov škodljivcev kot tudi pri višjih živalih, zato so se prizadevanja osredotočila na preučevanje razredov PI. Serinski in cisteinski PI se običajno nahajajo v semenih stročnic in v zrnju žit. Ker ti PI vplivajo na prehransko kakovost semen, so dolga leta veljali za pomemben antinutritivni dejavnik. Vendar pa je bilo v zadnjem desetletju ugotovljeno, da so nekateri serinski PI koristni za ljudi in živali, saj imajo bioaktivni, terapevtski ali imunoterapevtski učinek. Med serinskimi proteinazami sta najbolj razširjena tripsin in himotripsin, zato se njuna inhibicija pogosto obravnava kot merilo aktivnosti vseh PI. V zadnjih nekaj letih se raziskovalni skupini s Kmetijskega inštituta Slovenije in Inštituta za poljščine in zelenjadnice Novi Sad ukvarjata z razvojem protokolov za merjenje aktivnosti inhibitorjev tripsina in himotripsina v različnih stročnicah. Razviti so bili protokoli za merjenje aktivnosti inhibitorja tripsina (TIA) v semenih navadnega fižola, grahorja in boba ter protokol za ugotavljanje TIA v strokih navadnega fižola. Vzpostavljena je bila tudi metodologija za merjenje aktivnosti inhibitorja himotripsina (CIA) v grahorju. Vsi zgoraj navedeni rezultati so povezani tudi s prvo fazo nacionalnega projekta SafeSeed, katerega cilj je (i) odkriti akcesije sončnic, koruze, žit in stročnic z najvišjo stopnjo aktivnosti serinskih in cisteinskih PI; (ii) izolirati najbolj razširjene PI in (iii) jih uporabiti pri biološkem nadzoru skladiščnih škodljivcev.

Ključne besede: prebava beljakovin, inhibitorji proteinaz, serinske proteinaze, antinutritivni faktor

Zahvala. Študija je bila podprta s projektom bilateralnega sodelovanja med Republiko Slovenijo in Republiko Srbijo (BI-RS/23-25-042) ter projektom "New biorational methods for stored seed pest control and protection: To serve and prevent (SafeSeed)" (23-SSF-PRISMA-113), ki ga financira Sklad za znanost Republike Srbije.

[30] Dr., Institute of Field and Vegetable Crops, Novi Sad, Serbia, e-pošta: nevena.nagl@ifvcns.ns.ac.rs

Proteinase inhibitors - roles and applications in current crop production

Essential amino acids are obtained through the breakdown of dietary proteins by enzymes called proteinases. The function of proteinases is to release peptides and amino acids from dietary proteins in order to meet the organism's nutritional requirements. Herbivores (animals and insects) absorb all the necessary proteins by consuming plants. Therefore, plants have evolved defence mechanisms to minimize predation and one of these mechanisms is the ability to be an unacceptable food source. Plants produce a number of secondary metabolites, including proteinase inhibitors (PIs), which interfere with protein digestion by inhibiting a proteinase activity in the gut. Once ingested, PIs inactivate proteinases in the digestive tract, reducing protein digestibility and adsorption, inducing pancreatic hypertrophy and inhibiting growth. Of the various classes of plant proteinases, serine and cysteine proteinases are the most abundant in the digestive systems of economically important pest classes and in higher animals, which is why efforts have focussed on studying these PI classes. Serine and cysteine PIs are generally found in the seeds of legumes and in the grains of cereal crops. As these PIs affect the nutritional quality of seeds, they were considered an important anti-nutritional factor for many years. However, in the last ten years it has been recognised that some serine PIs are beneficial to humans and animals as they are bioactive, therapeutic or immunotherapeutic. Among serine proteinases, trypsin and chymotrypsin are the most abundant, so their inhibition is often considered as the measure of activity of all PIs. In the last few years, research groups from Agricultural Institute of Slovenia and the Institute of Field and Vegetable Crops Novi Sad have been working on development of protocols for measuring activity of trypsin and chymotrypsin inhibitors in different legumes. Protocols for measuring trypsin inhibitor activity (TIA) in seeds of common bean, grass pea and faba bean have been developed, as well as the protocol for TIA detection in pods of common bean. Methodology for measuring chymotrypsin inhibitor activity (CIA) in grass pea has been also established. All above mentioned results are also tied to first phase of national project SafeSeed, whose aims are to (i) detect accessions of sunflower, maize, small grains and legumes with the highest level of activity of serine and cysteine PIs; (ii) isolate the most abundant PIs and (iii) use them in biological control of storage pests.

Keywords: protein digestion, proteinase inhibitors, serine proteinases, antinutritional factor

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Novi zdravstveni vidiki lokalnih genskih virov *Allium* vrst

Marina ANTIĆ[31]

Rod *Allium* je razširjen na širokem geografskem območju in ga pogosto povezujemo z užitnimi vrstami, kot sta česen in čebula. Nedavne študije so poudarile doslej neizkoriščen potencial lokalnih genskih virov, ki spadajo v rod *Allium*, zlasti v smislu njihovih zdravilnih učinkov. Vrste iz rodu *Allium* so znane po ugodnem vplivu na srčno-žilni sistem, vključno z zniževanjem krvnega tlaka, antikoagulantnim delovanjem in učinki zniževanja holesterola. V zadnjem času so predmet pozornosti tudi zaradi svojih nevroprotektivnih lastnosti, še posebej v kontekstu nevrodegenerativnih bolezni, kot je demenca. Številni sekundarni metaboliti, prisotni v teh vrstah, zlasti žveplove organske spojine, kot so dialil sulfid (DAS), dialil disulfid (DADS) in dialil trisulfid (DATS), so pokazali velik potencial pri zaviranju aktivnosti acetilholinesteraze (AChE) in butirilholinesteraze (BChE). Ta dva encima imata ključno vlogo pri patogenezi Alzheimerjeve bolezni.
Naša raziskava obravnava fitokemično sestavo, antioksidativno aktivnost in potencialne terapevtske učinke različnih lokalno prilagojenih genotipov vrst *Allium*. Raziskava je bila izvedena na 22 reprezentativnih vzorcih, pridelanih v Sloveniji, ki so del zbirke genske banke Kmetijskega inštituta Slovenije. Študija poudarja pomen ohranjanja lokalnih genskih virov ter njihov potencial kot naravne intervencije za nevrodegenerativne bolezni. Poleg tega izpostavlja pomen lokalnih genskih virov za zdravje ter spodbuja nadaljnje raziskave njihovih koristi, kar prispeva k razvoju trajnostnih kmetijskih praks in ohranjanju biotske raznovrstnosti.
Ključne besede: *Allium*, lokalno prilagojeni genotipi, nevrodegenerativne bolezni
Zahvala. Raziskavo sofinancira Ministrstvo za znanstveni in tehnološki razvoj in visoko šolstvo Republike Srbske v okviru Bilateralnega projekta med Bosno in Hercegovino in Republiko Slovenijo "Karakterizacija lokalnih genskih virov rodu *Allium* za njihovo ohranitev in trajnostno uporabo" (Pogodba št. 19.032/966-4-1/23). Podpira ga tudi Agencija Republike Slovenije za raziskovalno in inovacijsko dejavnost (BI-BA/24-25-043).

Ptujska rdeča onion bulbs
Čebulice čebule Ptujska rdeča

Cross-section of the Ptujska rdeča onion bulbs
Prerez čebulic čebule Ptujska rdeča

[31] Dr., University of Banja Luka, Institute of Genetic Resources, Banja Luka, Republic of Srpska, Bosnia and Herzegovina, e-pošta: marina.antic@igr.unibl.org

New health aspects of local genetic resources of *Allium* species

The genus *Allium* is distributed across a wide geographical area and is most commonly associated with its edible species such as garlic and onion. Recent studies have emphasised the hitherto untapped potential of the locally adapted genetic resources inherent to the *Allium* genus, particularly in terms of their salutary effects. Species belonging to *Allium* genus are renowned for their favourable impact on the cardiovascular system, including the reduction of blood pressure, anti-aggregatory action and cholesterol-lowering effects. Recently, they have also been the subject of attention with regard to their neuroprotective properties, particularly in the context of neurodegenerative diseases such as dementia. A number of secondary metabolites present in *Allium* species, particularly organosulfur compounds such as diallyl sulphide (DAS), diallyl disulphide (DADS) and diallyl trisulfide (DATS), have demonstrated considerable potential in inhibiting the activity of acetylcholinesterase (AChE) and butyrylcholinesterase (BChE), two enzymes that play a pivotal role in the pathogenesis of Alzheimer's disease. This research investigates the phytochemical composition, antioxidant activity and potential therapeutic effects of various locally adapted genotypes of *Allium* species. The research was conducted on 22 representative samples grown in Slovenia that are part of the collection of the gene bank of Agricultural Institute of Slovenia. This research emphasises the importance of conserving local genetic resources, demonstrating their potential as natural interventions for neurodegenerative diseases. Furthermore, it highlights the significance of local genetic resources and encourages further investigation into their health benefits, thus contributing to the development of sustainable agricultural practices and the preservation of biodiversity.

Keywords: *Allium*, locally adapted genotypes, neurodegenerative diseases

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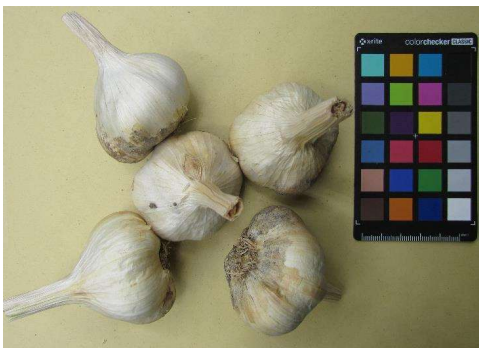


Ptujski jesenski garlic bulbs
Čebulice česna Ptujski jesenski

Cross-section of the Ptujski jesenski garlic bulbs
Prerez čebulic česna Ptujski jesenski

Vrednotenje izbranih genotipov in vzgoja križancev za proučevanje odpornosti hmelja (*Humulus lupulus* L.) na hudo viroidno zakrnelost hmelja

Andreja ČERENAK[32], Jernej JAKŠE, Helena VOLK, Lucija LUSKAR, Maja DOBRAJC, Uroš KOLENC, Tanja GUČEK in Sebastjan RADIŠEK

Viroid razpokanosti skorje agrumov (CBCVd – Citrus Bark Cracking Viroid) je v zadnjem desetletju opazno zaznamoval slovensko hmeljarstvo. Iz nepoznanega povzročitelja manj pomembne bolezni pri citrusih je postal dobro poznan povzročitelj hude viroidne zakrnelosti hmelja. V okviru potekajočega projekta smo izvedli križanja med različno tolerantnimi genskimi viri, znanimi sortami in moškim ameriškim divjim hmeljem, ki je izkazal delno odpornost oz. toleranco na CBCVd v predhodnih raziskavah. V steklenjaku smo posejali križance šestih družin križanj z namenom vnosa tolerantnosti na CBCVd v obstoječe sorte, ki bodo na njivo posajeni v 2025. Prav tako smo vzgojili več tisoč semen za izvajanje nadaljnjih genetskih analiz z namenom proučevanja mehanizmov odpornosti. Najpomembnejši del raziskave je bila postavitev ograjenega nasada 49 različnih genskih virov, torej sort hmelja, divjega hmelja in moških rastlin za namen določanja njihove tolerance. Vsak je posajen na 10-ih sadilnih mestih, od katerih pet rastlin izpostavljamo okužbi, preostale rastline pa služijo kot kontrola. Dostop v nasad imajo samo pooblaščene osebe in zunanji oskrbovalec nasada ob upoštevanju karantenskih fitosanitarnih pogojev, ki smo jih določili v posebnem protokolu dela. Z okuževanjem rastlin smo pričeli v letu 2023 in periodično nadaljevali tudi v letu 2024 v poletnih mesecih, ko so rastline najbolj dovzetne za okužbo. Vir okužbe so predstavljale referenčne donorske rastline, iz katerih smo pripravljali inokulum na osnovi rastlinskega soka. Zaradi dolge inkubacijske dobe, ki znaša na občutljivih genotipih nekaj mesecev do enega leta, smo v drugem delu vegetacije 2024 izvedli preverjanje uspešnosti okužb z molekularno analizo RT-qPCR. Prva bolezenska znamenja smo opazili v juliju 2024, ki pa so bila omejena samo na določene genotipe, ki izražajo visoko občutljivost. Prihodnje delo bo temeljilo na nadaljevanju okuževanja rastlin, pri katerih z RT-qPCR nismo potrdili okužbe, ter fenotipskem ocenjevanju okuženih rastlin. Vezano na razvoj potencialne zgodnje diagnostike okužbe hmeljne rastline s CBCVd preverjamo možnost uporabe biomarkerja izražene RNA (transkriptomski biomarker), ki se močno izraža ob začetku okužbe. Napravili smo diferencialno analizo izražanja genov hmelja po okužbi z viroidi CBCVd, HLVd in HSVd. V poskus smo vključili sorte Celeia (občutljiva na CBCVd), Styrian Cardinal (domnevno toleranten) in Styrian Wolf (domnevno odporen), ki smo jih vzorčili v zgodnjih stadijih umetne okužbe. Trenutno potekajo dodatne bioinformacijske študije na novo pridobljenih podatkih in pričakujemo, da bomo pridobili dodatne kandidatne transkripte in jih vključili v analize uporabe kot možne diagnostične biomarkerje.

Ključne besede: hmelj, *Humulus lupulus* L., CBCVd, huda viroidna zakrnelost hmelja, žlahtnjenje

Zahvala. Raziskava je financirana v okviru ciljnega raziskovalnega projekta (CRP V4 – 2203) 'Vrednotenje genotipov in vzgoja družin križanj za proučevanje odpornosti hmelja *Humulus lupulus* L. na hudo viroidno zakrnelost hmelja' ter programske skupine P4-0077 Kmetijske rastline – genetika in sodobne tehnologije.

[32] Dr., Inštitut za hmeljarstvo in pivovarstvo Slovenije, e-pošta: andreja.cerenak@ihps.si

Evaluation of selected genotypes and developing breeding lines of hop (*Humulus lupulus* L.) to study the resistance to severe hop stunt viroid disease

Citrus Bark Cracking Viroid (CBCVd) has marked the Slovenian hop industry in the last decade and noticeably marked Slovenian hop industry. It has evolved from an unknown cause of a minor citrus disease to a known cause of severe viroid stunting of hops. As part of the ongoing project, we have performed crosses between different tolerant genetic resources, known cultivars and male American wild hops, which have been shown in previous studies to be partially resistant or tolerant for CBCVd. Six families of crosses were sown in the greenhouse with the aim of introducing tolerance to CBCVd into existing varieties that will be planted in the field next year. We also collected several thousand seeds for further genetic analysis to learn more about the mechanisms of tolerance. The most important part of the project was the establishment of a fenced plantation of 49 different hop varieties, wild hops and male plants to determine their tolerance. There are 10 planting sites for each variety, five of which are exposed to the infection and the rest serve as controls. Access to the plantation is restricted to authorised personnel and the plantation's external plantation manager, taking into account the phytosanitary quarantine conditions that we have established with a special working protocol. We started infecting plants in 2023 and continued periodically in 2024 during the summer months, when plants are most susceptible to infection. The source of infection was the reference donor plants from which we prepared the sap-based inoculum. Due to the long incubation period, ranging from a few months to a year for the genotypes involved, we carried out a performance check using RT-qPCR molecular analysis in the second half of the 2024 growing season. The first signs of the disease were observed in July 2024 but were limited to a specific genotype with a high level of susceptibility. Further work was based on continued infection of plants in which we did not confirm infection by RT-qPCR and phenotypic assessment of infected plants. In connection with the development of potential early diagnostics for hop infection with CBCVd, we are investigating the possibility of using an expressed RNA biomarker (transcriptomic biomarker) that is highly expressed at the beginning of the infection. We performed a differential analysis of hop gene expression after infection with CBCVd, HLVd and HSVd viroids. We included the varieties Celeia (susceptible to CBCVd), Styrian Cardinal (presumably tolerant) and HSVd in the experiment. Further bioinformatic studies are currently underway on the newly acquired data. We expect to identify additional candidate transcripts and include them in analyses for use as potential diagnostic biomarkers.

Keywords: hop, *Humulus lupulus* L., CBCVd, severe hop stunt disease, breeding

Uporaba NGS tehnik pri žlahtnjenju rastlin: analiza heterogenosti barve semen pri kompozitnih populacijah navadnega fižola (*Phaseolus vulgaris* L.)

Eva PLESTENJAK[33], Mohamed NEJI, Vladimir MEGLIČ in Barbara PIPAN

Sposobnost prilagajanja na različne okoljske dejavnike, domestikacija in postopki žlahtnjenja so privedli do velike genetske raznolikost navadnega fižola (*Phaseolus vulgaris* L.). Slednja predstavlja osnovo za ohranjanje ekosistemov, omogoča prilagajanje spremenljivim razmeram v okolju in ustvarjanje novih sort. Barva semen predstavlja pomemben dejavnik izbire, zato je ključno poznavanje genetskih mehanizmov njene variabilnosti. V naši raziskavi smo se osredotočili na kompozitne populacije navadnega fižola, pri čemer vsako populacijo sestavlja od dva do pet različno obarvanih semen – fenotipov. Izmed 50 kompozitnih populacij navadnega fižola smo izbrali štiri, ki so po prvem letu izkazovale najvišjo stopnjo segregacije, ter še dve standardni sorti. Skupno je bilo na polju okarakteriziranih 19 individualnih fenotipov z uporabo 86 deskriptorjev v dveh zaporednih letih, listi pa so bili vzorčeni za molekularne analize. Izbrane populacije so bile poslane na sekvenciranje celotnega genoma (ang. whole genome sequencing; WGS). Z rezultati WGS smo identificirali več kot 8,6 milijona polimorfizmov posameznih nukleotidov (SNP), pri čemer sta imela kromosoma 4 in 1 največjo gostoto SNP-jev (11 %), kromosoma 3 in 6 pa najmanjšo. Za identifikacijo regij genoma, ki so povezane s spremembo barve semen, smo kompozitne populacije razdelili v dve skupini. Prva je vsebovala standardni sorti Golden Gate in ETNA ter kompozitno populacijo INCBN_03048, kjer po prvem letu kultivacije ni prišlo do spremembe barve semen, druga pa je vsebovala kompozitne populacije KIS Amand, SRGB_00189 in SRGB_00366, kjer je prišlo do spremembe barve semenske ovojnice. Z orodjema XP-CLR in XP-EHH smo identificirali 118 kandidatnih regij, povezanih s spremembo barve semen, med njimi pa je bilo največ fosfatidilinozitolnih signalnih poti. Poleg regulacijskih in strukturnih elementov rezultati nakazujejo pomembnost mehanizmov celičnega transporta pri pigmentaciji semen. Identifikacija in poznavanje omenjenih regij predstavljata dragoceno informacijo za uporabnost in pomen kompozitnih populacij navadnega fižola predvsem v ekološko usmerjenem žlahtnjenju rastlin.

Ključne besede: navadni fižol, barva semen, kompozitne populacije, žlahtnjenje, WGS

Štiri kompozitne populacije in dve standardni sorti, uporabljene v študiji
Four composite populations and two standard varieties used in this study

[33] Mag. mikrobiol., Kmetijski inštitut Slovenije, e-pošta: eva.plestenjak@kis.si

NGS technique applied in plant breeding: analysing seed colour heterogeneity in composite populations of common bean (*Phaseolus vulgaris* L.)

The ability to adapt to different environmental factors as well as domestication and breeding processes have led to a great genetic diversity of the common bean (*Phaseolus vulgaris* L.). This diversity is the basis for the preservation of ecosystems, adaptation to changing environmental conditions and the creation of new varieties. Seed colour is an important selection factor, which is why knowledge of the genetic mechanisms of its variability is crucial. In our research, we have focused on composite populations of common bean, where each population consists of two to five differently coloured seeds - phenotypes. From the 50 composite populations of common bean, we selected four that showed the highest level of segregation after the first year and two other standard varieties. A total of 19 individual phenotypes were characterised in the field in two consecutive years using 86 descriptors, and leaves were sampled for molecular analysis. Selected populations were sent for whole genome sequencing (WGS). The WGS results identified more than 8.6 million single nucleotide polymorphisms (SNPs), with chromosomes 4 and 1 having the highest density of SNPs (11%) and chromosomes 3 and 6 the lowest. To identify regions of the genome associated with the change in seed colour, the composite populations were divided into two groups. The first group comprised two standard varieties, Golden_Gate and ETNA, and the composite population INCBN_03048, which did not show any change in seed colour after the first year of cultivation, while the second group comprised the composite populations KIS_Amand, SRGB_00189 and SRGB_00366, which showed a change in seed colour. Using the XP-CLR and XP-EHH tools, we identified 118 candidate regions associated with seed colour change, most of which were phosphatidylinositol signalling pathways. In addition to the regulatory and structural elements, the results show us the importance of cellular transport mechanisms in seed pigmentation. The identification and knowledge of the above-mentioned regions provide valuable information on the usefulness and importance of common bean composite populations, especially in organically orientated plant breeding.

Keywords: common bean, seed colour, composite populations, breeding, WGS

Novi križanci krompirja, primerni za konvencionalno in ekološko pridelavo

Peter DOLNIČAR[34], Marion CHAMPAILLER in Nina KARČE POLJANŠEK

O programu žlahtnjenja na Kmetijskem inštitutu Slovenije (KIS), metodah dela in sprotnih dosežkih smo že večkrat poročali, med drugim tudi na Novih izzivih. Gre za klasičen program žlahtnjenja, ki se prične z odbiro staršev, nadaljuje s križanji, setvijo sejancev v prvem letu v rastlinjaku, ter saditvijo v naslednjih letih na polje, kjer poteka odbira na izbrane lastnosti. V prvem letu sejance umetno okužimo z virusom Y in opravimo množično odbiro na odpornost proti virusu Y krompirja. V naslednjih 5-ih do 6-ih letih sledi na polju množična odbira na kvalitativne in kvantitativne lastnosti. V prvem letu posadimo med 5.000 in 7.000 različnih genotipov krompirja, ki izvirajo iz 30 do 50 kombinacij križanj, vse po 1 rastlino na genotip. V naslednjih letih odbire se število odbranih klonov zmanjšuje, povečuje pa se število posajenih rastlin na klon. Od drugega leta na polju opravljamo tudi organoleptične analize kuhanega in ocvrtega krompirja po skali European Association for Potato Research. Vsako leto pri križancih iz kombinacij križanj z odpornimi starši z molekulskimi markerji določamo prisotnost *R* genov, ki povzročajo odpornost proti krompirjevi plesni. Najboljše križance po 6-ih do 7-ih letih uvrstimo v dvoletne poskuse s konvencionalno pridelavo ki služijo za predizbiro. Tem pa sledi po potrebi dodatno leto preskušanja najboljših še v sortnem poskusu. Najboljše potem uvrstimo v 2 do 3 letni postopek registracije sorte, ki vključuje VPU in RIN preskušanje. Od leta 2021 smo vse klone iz tretje generacije na polju in višjih generacij v okviru projekta ECOBREED pričeli preskušati tudi na ekoloških njivah KIS na IC Jablje. Pri vseh generacijah so po 4 gomolji na klon posajeni skupaj s standardnimi sortami z ustrezno zgodnostjo, odpornimi proti krompirjevi plesni, ki so že uveljavljane v ekološki pridelavi. Ocenjujemo rast in razvoj krompirjevke (v ekološki predelavi še pomembnejša saj močan vigor zagotavlja visok pridelek in dobro tekmovalnost s pleveli), pridelek in njegove lastnosti ter jedilno kakovost gomoljev. Da bi preizkušanje čim bolj približali realnim razmeram v ekološki pridelavo, smo v okviru participativnega žlahtnjenja v projektu ECOBREED pričeli s preizkušanjem križancev na 5-ih ekoloških kmetijah. Po koncu projekta smo v letih 2023 in 2024 nadaljevali s preizkušanjem na treh kmetijah: v Dobrepolju, v okolici Šentjerneja ter v Slatini pri Ponikvi. Za primerjavo sort na različnih lokacijah z različnim načinom kmetovanja so bila izbrana merila: datum sajenja, gostota sajenja, datum vznika (BBCH 009), datum sklepanja vrst (BBCH39), datum dozorevanja (BBCH 91), višina rastlin, prisotnost simptomov krompirjeve plesni in črne listne pegavosti, pridelek, velikost gomoljev, suha snov, tip kuhanja, sprememba barve mesa po kuhanju, napake gomoljev, pravilnost oblike gomoljev, globina očes. V konvencionalnih poskusih v konvencionalni pridelavi predizbire in sortnega preizkušanja na KIS je bilo leta 2023 preizkušanih 17, leta 2024 pa 43 križancev iz križanj v letih 2011–2017, medtem ko je bilo v poskuse na ekoloških kmetijah poslanih 13 križancev v letu 2023 in 21 križancev v letu 2024. Številni med njimi so dokazano odporni proti krompirjevi plesni in zato primerni tudi za ekološko pridelavo. Rezultati preizkušanj kažejo, da so nekateri križanci med najrodnejšimi ne glede na način pridelovanja (konvencionalno ali ekološko), medtem ko so drugi izrazito nadpovprečni le v enem načinu pridelave. Med rodnejše je bila pogosto uvrščena tudi slovenska sorta KIS Kokra, ki je že sedaj razširjena v ekološki pridelavi.

Ključne besede: *Solanum tuberosum,* krompir, križanci, ekološka pridelava

[34] Dr., Kmetijski inštitut Slovenije, e-pošta: peter.dolnicar@kis.si

New potato clones suitable for conventional and organic production

About the breeding programme at the Agricultural Institute of Slovenia, working methods and ongoing achievements have been reported on several occasions, including on New Challenges symposium. It is a classic breeding programme, starting with the selection of parents, followed by crosses, sowing of seedlings in the first year in the greenhouse, and planting in the field, where selection for selected traits takes place. In the first year, the seedlings are inoculated with the Y virus and a mass selection for resistance to potato virus Y is carried out. This is followed in the next 5 to 6 years by mass selection for qualitative and quantitative traits in the field, where between 5,000 and 7,000 different potato genotypes are planted in the first year from 30 to 50 cross combinations, all in single hills planting. In the following years of selection, the number of clones selected decreases, and the number of plants planted per clone increases. Since the second year, organoleptic analyses of boiled and fried potatoes have also been carried out in the field according to the EAPR scale. Each year, the presence of R genes conferring resistance to potato blight is determined by molecular markers in crosses from resistant cross combinations. The best crosses are entered into 2-year conventional pre-selection trials, followed by an additional year of best-clones in variety trials if necessary, and then a 2–3-year variety registration process including VCU and DUS trials. From 2021, all clones from the third generation in the field and higher generations have also been tested in the organic fields of KIS at IC Jablje as part of the ECOBREED project. In all generations, 4 tubers per clone are planted together with standard varieties, early ones, resistant to potato blight and already established in organic production. We are evaluating the growth and development of the potato plants, which is even more important in an organic production system, as a strong vigour ensures high yields and good competition with weeds, yield and yield characteristics and edible quality. To make the trials as close as possible to the real conditions of organic production, trials of crosses on 5 organic farms in the framework of the participatory breeding project ECOBREED have been started. After the end of the project, trials continued in 2023 and 2024 on 3 farms: in Dobrepolje, near Šentjernej and in Slatina near Ponikva. A panel of criteria was developed to compare varieties at different locations with different farming practices: date of planting, plant density, date of emergence (BBCH 009), date of canopy closure (BBCH39), date of senescence (BBCH 91), plant height, severity of late blight and early blight symptoms, yield, tuber size, dry matter, type of cooking, palatability of flesh after cooking, tuber disturbance, regularity of tuber shape, depth of eyes. In the conventional pre-selection and variety trials at KIS, 17 and 43 crosses from the 2011 to 2017 crossing years were tested in 2023 and 2024, respectively, while 13 and 21 crosses were sent for on-farm trials in 2023 and 2024. Many of them have proven resistance to potato blight and are therefore also suitable for organic production. The results of the trials show that some of the hybrids are among the most productive in both conventional and organic production, irrespective of the production method, while others are clearly above average in only one production method. The Slovenian variety KIS Kokra, which is already widespread in organic production, has also often been ranked among the most prolific.

Keywords: *Solanum tuberosum*, potatoes, breeding clones, organic production

Gensko spremenjene rastline krompirja, ki izražajo proteinske komplekse iz gliv rodu *Pleurotus*: nova strategija zatiranja koloradskega hrošča

Primož ŽIGON[35], Maja GRUNDER, Anastasija PANEVSKA, Anna COLL RIUS, Tjaša LUKAN, Karmen POGAČAR, Marko PETEK, Jaka RAZINGER, Kristina GRUDEN in Kristina SEPČIĆ

Proteinski kompleksi, pridobljeni iz ostrigarjev (*Pleurotus* sp.), zlasti kompleks pleurotolizin A2 (PlyA2) in pleurotolizin B (PlyB), so v interakciji z membranskimi sfingolipidi v *in vitro* prehranjevalnih testih pokazali specifično toksičnost za ličinke koloradskega hrošča (*Leptinotarsa decemlineata* Say). V tem prispevku predstavljamo nov pristop k varstvu krompirja, ki temelji na uporabi proteinskih kompleksov PlyA2/PlyB za razvoj transgenih rastlin krompirja sorte Désirée. V poskusih smo dokazali, da so bile transgene rastline, pri katerih je biosinteza PlyA2 lokalizirana v vakuoli, PlyB pa v endoplazemskem retikulumu, učinkovito zavarovane pred ličinkami koloradskega hrošča ter hkrati ohranile normalen fenotip, brez negativnega vpliva na pridelek. V *in vivo* prehranjevalnih testih smo pri eni izmed transformiranih linij ugotovili značilno povečanje smrtnosti in manjši prirast mase ličink, ki so bile v povprečju pet- do šestkrat lažje od ličink na kontrolnih rastlinah. Poleg tega se je le manjši delež ličink (11–37 %), ki so zaužile transgene krompirjeve rastline, uspešno preobrazil v odrasle hrošče. Analiza transkriptoma ličink koloradskega hrošča, izpostavljenih kompleksom PlyA2/PlyB, je v le-teh razkrila znake splošnega stresa, brez znakov morebitnega razvoja odpornosti, povezane s funkcionalno inaktivacijo sfingolipidnih receptorjev PlyA2/PlyB. Rezultati raziskave predstavljajo temelje za razvoj inovativnega in okolju prijaznega načina zatiranja koloradskega hrošča in prispevajo k razvoju trajnostnih metod varstva rastlin.

Ključne besede: bioinsekticid, genska transformacija, *Leptinotarsa decemlineata* Say *Solanum tuberosum*, egerolizin, zatiranje ličink

Poškodbe listov zaradi prehranjevanja ličink koloradskega hrošča na transgenih (levo) in ne-transgenih (desno) rastlinah krompirja.

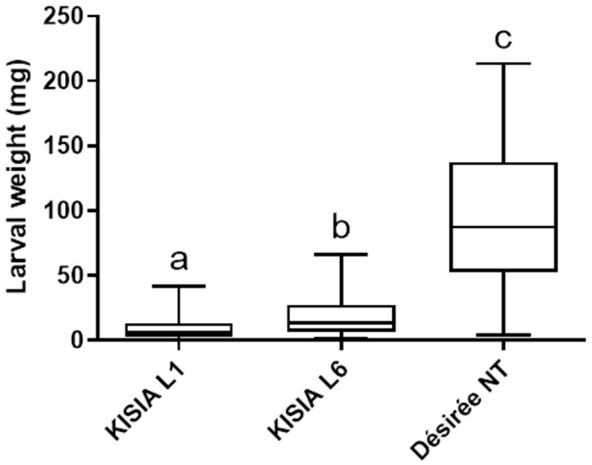
Leaf damage caused by Colorado potato beetle larvae feeding on transgenic (left) and non-transgenic (right) potato plants.

[35] Mag. inž. agr., Kmetijski inštitut Slovenije, e-pošta: primoz.zigon@kis.si

Genetically modified potato plants expressing protein complexes from fungal genus *Pleurotus*: A novel strategy for Colorado Potato Beetle Control

Protein complexes derived from oyster mushrooms (*Pleurotus* sp.), specifically pleurotolysin A2 (PlyA2) and pleurotolysin B (PlyB) complexes which act by interaction with insect-specific membrane sphingolipids, have demonstrated toxicity against Colorado potato beetle (*Leptinotarsa decemlineata* Say; CPB) larvae in *in vitro* feeding trials. In this study, we present a novel approach to protection of potato plants based on the *in-planta* production of PlyA2/PlyB protein complexes, exemplified by the development of transgenic potato plants of the cv Désirée. These transgenic plants, in which PlyA2 is targeted to the vacuole and PlyB to the endoplasmic reticulum, effectively repel CPB larvae while maintaining normal phenotype with no negative effect on yield. In *in vivo* feeding tests, one of the transformed lines showed a significant increase in mortality and reduced weight gain of larvae, which were on average five to six times lighter than larvae on control plants. In addition, only a small percentage (11–37%) of the larvae that consumed transgenic potato plants were able to mature into adult beetles. Transcriptome analysis of CPB larvae exposed to PlyA2/PlyB complexes revealed signs of general stress, with no indication of potential resistance development linked to the functional inactivation of PlyA2/PlyB sphingolipid receptors. The research provides an innovative and environmentally friendly method of the CPB control and contributes to the development of sustainable crop protection strategies.

Keywords: aegerolysin, biopesticide, plant transformation, *Leptinotarsa decemlineata* Say, *Solanum tuberosum*, larval toxicity



Povprečna masa ličink koloradskega hrošča po 10 dneh prehranjevanja na transgenih (KISIA L1 in KISIA L2) in ne-transgenih (Désirée NT) rastlinah krompirja.

Average weight of Colorado potato beetle larvae after 10 days of feeding on transgenic (KISIA L1 and KISIA L2) and non-transgenic (Désirée NT) potato plants.

Potencial prve klasične slovenske sorte industrijske konoplje z imenom Fiona

Tamara KOROŠEC[36] in Marko FLAJŠMAN

Eden izmed začetnih in temeljnih načinov za izboljšanje storilnosti poljedelske pridelave je izbira primernega rastlinskega materiala za pridelavo, to je primerne sorte. V Sloveniji do leta 2021 nismo imeli slovenskih sort industrijske konoplje in smo bili zaradi tega povsem odvisni od tujih sort in v veliki meri tudi od tujega semenskega materiala. Tuje sorte niso prilagojene slovenskim rastnim razmeram, ker niso bile požlahtnjene v naših razmerah. V začetku leta 2021 smo na Biotehniški fakulteti, Univerze v Ljubljani, na sortno listo vpisali prvo sorto slovenske industrijske konoplje z imenom Fiona, ki je rezultat lastnega žlahtniteljskega dela in je zaradi tega bolj prilagojena na slovenske rastne razmere. Da bi preverili ali ima sorta potencial v realni pridelavi, smo v letu 2024 izvedli preizkus na šestih kmetijah, v različnih regijah, na skupno 13-ih ha površin, z uporabo različnih agrotehničnih ukrepov. Poleg že registrirane sorte Fiona smo preizkusili še dve liniji konoplje, ki sta trenutno še v postopku uradnega preizkušanja (FxGS in FxF). Na kmetiji v Podravju smo preizkušali ukrep vršičkanja zaradi lažjega strojnega spravila. Pri setveni normi 30 kg/ha semena je bil pridelek svežih semen in stebel pri vzorčenju pri nevršičkanih rastlinah večji (2,2 t/ha in 37,2 t/ha) kot pri vršičkanih (1,9 t/ha in 23,5 t/ha). Vršičkanje se je izkazalo kot ugoden ukrep za spravilo, saj so bile nevršičkane rastline v povprečju za en meter višje in je bila strojna žetev močno otežena. Na kmetiji v Prekmurju smo s tehnologijo setve na grebene z medvrstno razdaljo 60 cm preizkušali 3 setvene norme (20, 30 in 40 kg/ha). Najboljše rezultate smo dosegli pri setveni normi 30 kg/ha (0,8 kg/ha semen in 9,7 t/ha stebel). Na kmetiji v Beli krajini smo preizkušali dva roka setve (konec aprila, konec maja), gostoto setve in ukrep vršičkanja. Skoraj dvakrat več pridelka smo izmerili pri pozni setvi (785 kg/ha) kot pri zgodnji (413 kg/ha). Najbolje se je obnesla setvena norma 30 kg/ha. Vršičkane rastline so dale 128 kg/ha manj pridelka semen kot nevršičkane. Na kmetiji na Dolenjskem smo prav tako testirali dva roka setve, gnojenje z dušikom in vršičkanje. Drugi rok setve je tudi tukaj bil bolj uspešen (1,1 t/ha semen) kot prvi (0,7 t/ha). Gnojenje z 80 kg dušika na hektar je pomenilo 195 kg/ha več semen kot gnojenje s 30 kg dušika na hektar. Prav tako so tudi v tem primeru vršičkane rastline obrodile približno 100 kg/ha manj pridelka semen kot nevršičkane. Na kmetiji v okolici Novega mesta smo pri primerjavi sort Fiona in potencialnih novih sort FxGS ter FxF največ semena pridelali pri potencialni novi sorti FxGS (0,85 t/ha), sledila je FxF (0,7 t/ha) in Fiona (0,5 t/ha). Povprečen odstotek surovih beljakovin (SB) in surovih maščob (SM) v semenih je bil 22,1±0,85 SB in 28,65±0,95 SM. Med kmetijami ni bilo značilnih razlik v SB in SM. Pri potencialni sorti FxGS je bil odstotek SB nekoliko majši (20,7 %), odstotek SM pa večji (29,9 %). V praktičnih pogojih pridelave so se pridelki semen sorte Fiona tako znašali med 416 kg/ha do 2250 kg/ha. Poznejši roki setve (sredina in konec maja) so vplivali na večji pridelek semen. Optimalna setvena norma je bila 30 kg/ha. Vršičkanje rastlin je zmanjšalo pridelek, vendar ugodno vplivalo na možnost strojnega spravila posevka. Več dušika sicer poveča pridelek, vendar poveča tudi višino rastlin, kar slabo vpliva na strojno spravilo. Novi kandidatni sorti sta v poljskem poskusu pokazali dober potencial za vpeljavo v pridelavo v Sloveniji.

Ključne besede: industrijska konoplja, slovenske sorte, Fiona

[36] Dr., Kmetijsko gozdarski zavod Maribor, e-pošta: tamara.korosec@kmetijski-zavod.si

The potential of the first regular Slovenian variety of industrial hemp named Fiona

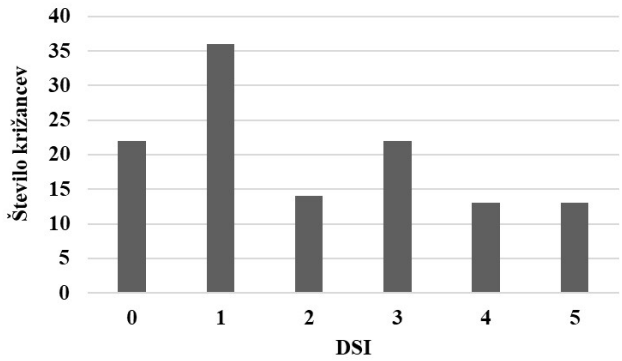
One of the first and fundamental methods of improving the productivity of agricultural crops is the selection of suitable plant material, especially suitable varieties. Until 2021, Slovenia did not have any domestic varieties of industrial hemp, so the country was completely dependent on foreign varieties and thus on foreign seed material. Foreign varieties are not adapted to Slovenian growing conditions as they have not been bred in the local environment. At the beginning of 2021, the Biotechnical Faculty of the University of Ljubljana registered the first Slovenian industrial hemp variety, named Fiona, which is the result of domestic breeding efforts and is therefore better adapted to Slovenian conditions. To assess its potential in field cultivation, trials were conducted in 2024 on six farms across different regions, covering a total of 13 hectares with various agronomic measures. In addition to the registered variety Fiona, two other breeding lines currently undergoing official testing (*FxGS* and *FxF*) were included in the trials. On a farm in the Podravje region, topping was tested as a measure to facilitate mechanical harvesting. At a sowing rate of 30 kg/ha, untopped plants yielded higher amounts of fresh seed and stalks (2.2 t/ha and 37.2 t/ha, respectively) compared to topped plants (1.9 t/ha and 23.5 t/ha). Topping proved to be advantageous for harvesting, as untopped plants were, on average, one meter taller, making them difficult to harvest mechanically. On a farm in Prekmurje, ridge sowing with 60 cm row spacing was tested with three sowing rates (20, 30, and 40 kg/ha). The best results were achieved with a sowing rate of 30 kg/ha (0.8 t/ha of seeds and 9.7 t/ha of stalks). On a farm in Bela Krajina, two sowing dates (late April and late May), sowing density, and topping were tested. Late sowing resulted in almost double the yield (785 kg/ha) compared to early sowing (413 kg/ha). The optimum sowing rate was 30 kg/ha. Topped plants produced 128 kg/ha less seed than untopped plants. On a farm in Dolenjska, two sowing dates, nitrogen fertilisation, and topping were tested. As in other trials, the later sowing date resulted in higher yields (1.1 t/ha) compared to the earlier date (0.7 t/ha). Fertilising at 80 kg of N/ha resulted in 195 kg/ha more seed compared to 30 kg of N/ha. Topped plants again yielded approximately 100 kg/ha less seed than untopped plants. Comparing the Fiona variety with the *FxGS* and *FxF* lines, the highest seed yield was achieved with the potential new variety *FxGS* (0.85 t/ha), followed by *FxF* (0.7 t/ha) and Fiona (0.5 t/ha). The average crude protein (CP) and crude fat (CF) content of in the seeds was 22.1% ± 0.85 CP and 28.65% ± 0.95 CF. There were no significant differences in CP and CF percentages between farms, although *FxGS* had a slightly lower CP percentage (20.7%) and a higher CF percentage (29.9%) than Fiona. Under practical growing conditions, Fiona yields ranged from 416 kg/ha to 2,250 kg/ha. Later sowing dates (mid to late May) resulted in higher seed yields. The optimum sowing rate was 30 kg/ha. Topping reduced yields but improved the feasibility of mechanical harvesting. Increased nitrogen application increased yields but also increased plant height, which negatively affected mechanical harvesting. The new candidate varieties showed good potential for introduction into production in Slovenia under field trial conditions.

Keywords: industrial hemp, Slovenian varieties, Fiona

Fenotipsko ocenjevanje odpornosti križancev na verticilijsko uvelost hmelja kot osnova za nadaljnje asociacijske študije

Lucija LUSKAR[37], Jernej JAKŠE, Sebastjan RADIŠEK in Andreja ČERENAK

Žlahtnjenje hmelja (*Humulus lupulus* L.) je usmerjeno tako v izboljšanje pivovarskih kot tudi agronomskih lastnosti, med katerimi najbolj izstopajo odpornosti na bolezni, predvsem na hmeljevo peronosporo (*Pseudoperonospora humuli*), hmeljevo pepelovko (*Podosphaera macularis*), verticilijsko uvelost hmelja (*Verticillium nonalfalfae* in *V. dahliae*) in zadnja leta tudi na hudo viroidno zakrnelost hmelja, ki jo povzroča viroid razpokanosti skorje agrumov (citrus bark cracking viroid; CBCVd). Verticilijska uvelost hmelja je bolezen, ki se odraža v interakciji med fitopatogenimi glivami iz vrst *V. dahliae* in *V. nonalfalfae* in občutljivimi kultivarji hmelja. *V. nonalfalfae* je tipična talna hemibiotrofna gliva, ki lahko prezimi v tleh, na obolelih rastlinah in v koreninah kot trajni micelij. Hife ali konidiji najdejo pot v prevodni sistem skozi zdrave ali poškodovane mlade korenine. Po naselitvi korenin micelij nadaljuje pot po prevodnem sistemu, kjer se začne močno razmnoževati in tvoriti konidije, ki se s sokom prenašajo po rastlini. Ker je hmelj trajnica, lahko *V. nonalfalfae* povzroči popolno uničenje nasada in posledično večjo gospodarsko škodo. Žlahtnjenje hmelja je predvsem zaradi osnovnih lastnosti hmelja (dvodomnost, heterogenost, dolgo juvenilno obdobje) dolgotrajen postopek. Pridobivanje fenotipskih podatkov za odpornost na verticilijsko uvelost prispeva k še dodatni upočasnitvi procesa. Z željo po pohitritvi žlahtniteljskega procesa želimo s tehnikami visokozmogljivega sekvenciranja proučiti genetsko ozadje interakcije med rastlino in glivo in ga povezati s pridobljenimi fenotipskimi rezultati. Velik nabor fenotipskih rezultatov poveča možnost za odkritje ključnih regij. S pripravljenim inokulumom letalnega patotipa *V. nonalfalfae* smo okužili več kot 150 križancev med odporno angleško sorto Wye Target in občutljivo žlahtniteljsko linijo BL 2/1 (12 klonov vsakega križanca). Po pojavu simptomov smo v tedenskih intervalih določali bolezenski indeks DSI (angl. *disease severity index*) z ocenami od 0 do 5 na podlagi lestvice za ocenjevanje pojava bolezenskih znamenj na listih (0 = ni pojava bolezenskih znamenj, 5=81–100 % listne površine kaže bolezenska znamenja). Bolezenski indeks (graf) smo uspeli določiti pri 120 križancih. Največ križancev ima oceno 1 (36), kar pomeni 1-20 % površine listov s simptomi. V nadaljevanju bomo v sklopu asociacijskih študij celotnega genoma povezali fenotipske podatke z genotipskimi



Ključne besede: žlahtnjenje, hmelj, verticilij, bolezenski indeks, DSI

Prikaz števila križancev glede na 6 ocen bolezenskega indeksa.
Graph showing the number of F1 full-sib genotypes according to the 6 disease index scores.

[37] Mag. biotehnol., Inštitut za hmeljarstvo in pivovarstvo Slovenije, e-pošta: lucija.luskar@ihps.si

Phenotypic assessment of F1 full-sib genotypes with segregating resistance to hop verticillium wilt as basis for further association studies

Hop (*Humulus lupulus* L.) breeding is focused on improving both brewing and agronomic traits, the most important of which are resistance to diseases, especially hop peronospora (*Pseudoperonospora humuli*), hop powdery mildew (*Podosphaera macularis*), verticillium wilt (*Verticillium nonalfalfae*) and, in recent years, also to severe hop stunting caused by Citrus bark cracking viroid (CBCVd). Verticillium wilt of hop is a disease caused by the interaction between phytopathogenic fungi of the *V. dahliae* and *V. nonalfalfae* species and susceptible hop cultivars. *V. nonalfalfae* is a typical soil-borne hemibiotrophic fungus that can overwinter as a persistent mycelium in the soil, on infected plants, and in roots. Hyphae or conidia enter the vascular system through healthy or damaged young roots. After colonising the roots, the mycelium spreads through the vascular system, where it starts to proliferate significantly, forming conidia that are transported through the plant with the sap. As hops ere a perennial crop, *V. nonalfalfae* can cause complete destruction of the crop and, consequently, significant economic damage.

Hop breeding is a time-consuming process mainly due to the nature of hops (dioecism, heterogeneity, long juvenile period). Obtaining phenotypic data for resistance to verticillium wilt further slows down the process. To speed up the breeding process, we want to use high-throughput sequencing techniques to study the genetic background of the plant-fungus interaction and relate it to the phenotypic results obtained. A large set of phenotypic data increases the chance of identifying key regions. Using a prepared inoculum of the virulent *V. nonalfalfae* pathotype, we infected over 150 F1 full-sib genotypes from the family of the resistant English variety Wye Target and the susceptible breeding line BL 2/1 (12 clones per genotype). After symptom development, we assessed the disease severity index (DSI) at weekly intervals, scoring from 0 to 5 on a leaf disease symptom scale (0 = no disease symptoms, 5 = 81-100% of leaf surface showing disease symptoms). We were able to determine the disease index for 120 of F1 full-sib genotypes (graph). The majority have a score of 1 (36), indicating 1-20% leaf surface with symptoms. In the next phase, we will link the phenotypic data with genotypic data in a genome-wide association study.

Keywords: breeding, hop, verticillium, disease severity index, DSI

Simptomi verticilijske uvelosti hmelja na enem izmed križancev.
Symptoms of verticillium wilt of hops on one of the F1 full-sib genotypes.

Izražanje izbranih transkriptov v zgodnjih fazah okužbe hmelja s CBCVd: primerjava treh sort

Helena VOLK, Sebastjan RADIŠEK, Andreja ČERENAK in Jernej JAKŠE[38]

Viroid razpokanosti skorje agrumov (CBCVd) predstavlja veliko grožnjo pridelavi hmelja (*Humulus lupulus* L.), saj povzroča močne bolezenske znake, zmanjšan pridelek in posledično znatno gospodarsko škodo. Zgodnje odkrivanje okužb s CBCVd je ključnega pomena za nadzor širjenja tega viroida in za zmanjšanje škode, ki jo povzroča. V predstavljeni raziskavi smo preučili vzorce izražanja dveh transkriptov, imenovanih 1902 in 94443, da bi ugotovili, ali lahko služita kot zgodnja pokazatelja okužbe hmelja s CBCVd pred razvojem bolezenskih znakov. V predhodni RNA-seq študiji sta namreč pokazala močno izražanje pri viroidnih rastlinah, medtem ko se pri zdravih kontrolah nista izražala ali v zelo omejenem obsegu. Raziskava se je osredotočila na tri sorte hmelja: Celeia (občutljiva na CBCVd), Styrian Cardinal (domnevno toleranten) in Styrian Wolf (domnevno odporen).
Brezvirusne in brezviroidne sadike hmelja smo okužili s CBCVd z uporabo metode cepljenja korenin. Liste cepljenih rastlin smo vzorčili štiri in pet mesecev po okužbi, pred pojavom vidnih bolezenskih znakov. Nivo transkriptov 1902 in 94443 smo določili s kvantitativnim PCR (qPCR), rezultate pa normalizirali s standardnim referenčnim genom DRH1. qPCR analiza je pokazala, da sta bila oba transkripta prisotna tudi pri kontrolnih rastlinah, ki niso bile okužene s CBCVd, kar je lahko tudi posledica stresa, ki ga povzroči postopek cepljenja. Pri okuženih rastlinah sorte Styrian Wolf smo najvišje izražanje obeh transkriptov zaznani štiri mesece po okužbi, vendar je to znatno upadlo do petega meseca. Ravno nasprotno pa smo pri okuženih rastlinah sorte Styrian Cardinal določili najvišje izražanje obeh transkriptov pri petih mesecih. Pri okuženih rastlinah sorte Celeia smo nivo izražanja ocenjevali le pri štirih mesecih, saj so bili podatki pri petih mesecih nejasni zaradi majhnega števila okuženih rastlin.
Ugotovili smo, da se transkripta 1902 in 94443 izražata v odzivu na okužbo s CBCVd, vendar njihovo izražanje najverjetneje lahko inducirajo tudi drugi stresni dejavniki, npr. poškodbe. To jih naredi manj zanesljive markerje za detekcijo zgodnje okužbe z viroidi. Začasno povečanje izražanja transkriptov pri sorti Styrian Wolf nakazuje, da bi lahko služili kot pokazatelj zgodnje okužbe, vendar pa upad izražanja pri 5 mesecih odpira vprašanje o konsistentnosti izražanja skozi čas. Poleg tega različni vzorci izražanja, opaženi pri vsaki sorti hmelja, nakazujejo, da bi markerja morda bila specifična za določeno sorto. Zaradi tega bi bilo potrebno uporabiti kombinacijo več markerjev. Upad izražanja transkriptov, ko okužba napreduje, pomeni, da bi ti markerji lahko bili učinkoviti le v omejenem časovnem okviru po okužbi.
S to raziskavo smo dobili prvi vpogled v izražanje transkriptov 1902 in 94443 v odzivu na okužbo s CBCVd pri hmelju. Čeprav je začetna bioinformatska analiza nakazovala njihov potencial za uporabo kot zgodnje markerje okužbe, so rezultati qPCR analize v časovni seriji razkrili kompleksnosti na katere najverjetneje vplivajo cepljenje in ostali stresni dejavniki iz okolja. Prihodnje raziskave bi morale vključiti večje število vzorcev, dodatne časovne točke in nadzorovane okoljske pogoje, da bi bolje razumeli vlogo teh transkriptov. Predlagamo tudi razširitev nabora kandidatov za markerje za zgodnje odkrivanje okužb CBCVd pri hmelju. Z odkritjem ustreznih markerjev zgodnje okužbe bi lahko pripomogli k učinkovitemu upravljanju bolezni in zaščitil pridelavo hmelja pred nezaželenimi vplivi okužb s CBCVd.
Ključne besede: hmelj, viroid, CBCVd, qPCR, zgodnje odkrivanje okužbe, molekularni markerji, izražanje transkriptov

[38] Prof. dr., Univerza v Ljubljani, Biotehniška fakulteta, e-naslov: jernej.jakse@bf.uni-lj.si

Expression of selected transcripts in the early stages of hop infection with CBCVd: comparison of three cultivars

Citrus Bark Cracking Viroid (CBCVd) is a major threat to hop (*Humulus lupulus* L.) cultivation, causing significant economic losses by weakening plants and reducing yields. Detecting CBCVd infections early is essential for controlling its spread and minimizing damage. This study explores the expression patterns of two specific gene transcripts, named 1902 and 94443, to determine if they can serve as early indicators of CBCVd infection in hops before symptom onset. In a previous RNA-seq study, these transcripts showed strong expression in viroid-infected plants, whereas in healthy controls they were not expressed or were expressed only to a very limited extent. This research focused on three hop varieties: Celeia (susceptible to CBCVd), Styrian Cardinal (presumably tolerant), and Styrian Wolf (presumably resistant).

To conduct the study, virus and viroid-free hop plants were infected with CBCVd using a root grafting method. Leaf samples were collected at four- and five-months post infection (MPI), before any visible symptoms appeared. The levels of transcripts 1902 and 94443 were determined using quantitative PCR (qPCR), with results normalised to a standard reference gene, DRH1. The qPCR analysis showed that both transcripts were present even in control plants that were not infected by CBCVd, presumably because the grafting process itself caused stress. In the infected Styrian Wolf variety, the highest levels of both transcripts were detected at four months post-infection, but these levels significantly decreased by the fifth month. In contrast, the infected Styrian Cardinal variety showed peak transcript levels at five months. For the Celeia variety, high transcript levels were observed at four months, but the data at five months were inconclusive due to the low number of infected plants.

These results indicate that while transcripts 1902 and 94443 respond to CBCVd infection, their expression is also affected by other stress factors, i.e. wounding. This makes them less reliable as early markers of infection. The temporary increase in transcript levels in Styrian Wolf suggests they might indicate early infection, but the subsequent decrease raises concerns about their consistency over time. Additionally, the different expression patterns observed in each hop variety suggest that markers may need to be specific to each cultivar. Consequently, a combination of multiple markers should be used for more accurate detection. The decline in transcript levels as the infection progresses implies that these markers may only be effective within a limited time frame after infection.

This study provides initial insights into how transcripts 1902 and 94443 behave in response to CBCVd infection in hops. Although the initial bioinformatic analysis suggested their potential as early infection markers, the qPCR results in this time series revealed complexities influenced by grafting and other environmental stresses. Future research should involve larger sample sizes, additional time points, and controlled environmental conditions to better understand the role of these transcripts. Expanding the range of candidate markers will also be an important step toward identifying reliable molecular markers for the early detection of CBCVd infection in hops. Such advancements will aid in effective disease management and help protect hop production from the undesirable effects of CBCVd infection.

Keywords: hops, viroid, CBCVd, qPCR, early detection, molecular markers, transcript expression

Mehanizmi dvojne inhibicije acetilholinesteraze in butirilholinesteraze z alicinom: terapevtski potencial

Relja SURUČIĆ[39], Marina ANTIĆ, Barbara PIPAN in Lovro SINKOVIČ

Dvojna inhibicija acetilholinesteraze (AChE) in butirilholinesteraze (BuChE) z alicinom je že bila opažena, vendar natančni mehanizmi do sedaj niso bili povsem jasni. Da bi to razjasnili, so bile izvedene raziskave molekularnega sidranja s programsko opremo YASARA Structure, ki so razkrile vpoglede v interakcije alicina s katalitičnim aktivnim mestom (CAS) in perifernim anionskim mestom (PAS) obeh encimov. Alicin je pokazal močnejšo afiniteto do AChE, pri čemer je energija znašala -5,068 kcal/mol. Ugotovljeno je bilo, da alicin tvori stabilne interakcije s ključnimi aminokislinami, kot sta Ser 203 in His 447 v CAS (*glej* Slika 1), kar kaže na to, da alicin vzpostavlja bistvene povezave, potrebne za zaviranje aktivnosti AChE. Nasprotno pa je alicin pokazal šibkejše vezanje na BuChE, z energijo vezave -4,327 kcal/mol. Čeprav alicin sodeluje z aminokislinami v bližini aktivnega mesta, je bilo opaženih manj pomembnih interakcij, kar odraža njegovo nižjo inhibitorno sposobnost za BuChE. Rezultati kažejo, da alicin selektivno zavira AChE, kar kaže na možnost njegove potencialne uporabe pri nevrodegenerativnih boleznih, kot je Alzheimerjeva bolezen, kjer ima inhibicija AChE ključno terapevtsko vlogo. Glede na naravno prisotnost alicina v česnu lahko postane dostopno in stroškovno učinkovito terapevtsko sredstvo. Prihodnje raziskave bi morale raziskati njegovo farmakokinetiko, biološko uporabnost in klinično učinkovitost, da bi izkoristili njegov terapevtski potencial.

Ključne besede: alicin, acetilholinesteraza, butirilholinesteraza, molekularni doking, nevrodegenerativne bolezni

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[39] PhD, University of Banja Luka, Banja Luka, Republic of Srpska, Bosnia and Herzegovina, e-pošta: relja.surucic@med.unibl.org

Mechanism insights into the dual inhibition of acetylcholinesterase and butyrylcholinesterase by allicin: therapeutic potential

Dual inhibition of acetylcholinesterase (AChE) and butyrylcholinesterase (BuChE) by allicin has been reported, but the precise mechanisms remained unclear. To address this, molecular docking studies using YASARA Structure software were conducted, revealing insights into the interactions of allicin with the catalytic active site (CAS) and peripheral anionic site (PAS) of both enzymes. Allicin showed a stronger preference for AChE, with a binding energy of -5.068 kcal/mol, forming stable interactions with key residues such as Ser 203 and His 447 in the CAS (*see* Figure 1). This indicates that allicin establishes critical connections essential for inhibiting AChE activity. In contrast, allicin demonstrated weaker binding to BuChE, with a binding energy of -4.327 kcal/mol. Although it interacts with residues near the active site, fewer significant interactions were observed, reflecting its lower inhibitory potential for BuChE. These results suggest that allicin selectively inhibits AChE, indicating the possibility of its potential use in neurodegenerative disorders such as Alzheimer's disease, where AChE inhibition plays a key therapeutic role. Given its natural abundance in garlic, allicin holds promise as an accessible and cost-effective therapeutic agent. Future research should explore its pharmacokinetics, bioavailability, and clinical efficacy to harness its therapeutic potential.

Keywords: allicin, acetylcholinesterase, butyrylcholinesterase, molecular docking, neurodegenerative disorders

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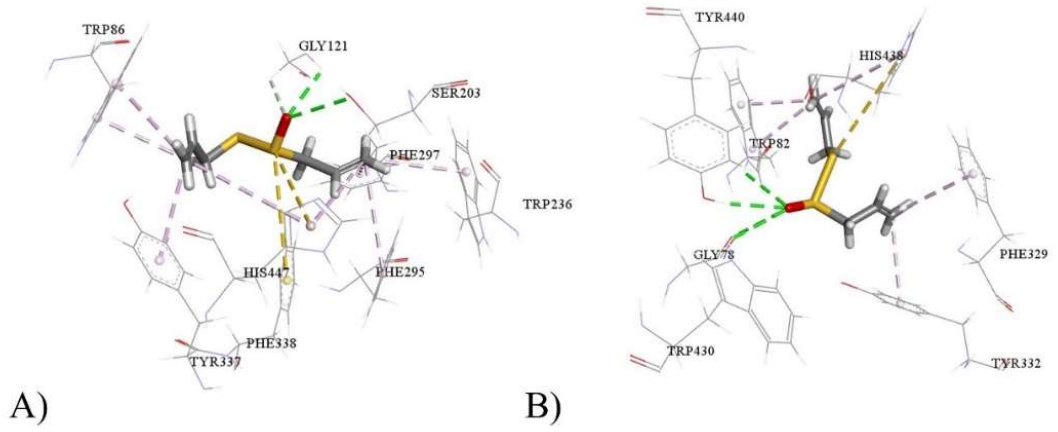

Interactions of allicin with A) acetylcholinesterase and B) butyrylcholinesterase
Interakcije alicina z A) acetilholinesterazo in B) butirilholinesterazo

Primernost dvodomnih in feminiziranih sort industrijske konoplje za namen pridelave kanabinoidov

Marko FLAJŠMAN[40], Miha VENGAR, Berkay SAKIZ, Luka BITEŽNIK, Roman ŠTUKELJ in Darja KOCJAN AČKO

Industrijska konoplja (*Cannabis sativa* L.) je vsestranska rastlina, ki jo že tisočletja uporabljamo v medicini, prehrani in za pridelavo vlaken. Njena pridelava je zaradi prisotnosti psihoaktivnega kanabinoida THC (Δ9-tetrahidrokanabinol) regulirana z zakonom. CBD (kanabidiol) in CBG (kanabigerol) nista psihotropna kanabinoida, a imata velike terapevtske koristi, ki so potrjene predvsem za CBD, nove raziskave pa kažejo tudi na pozitivne vplive CBG na zdravje ljudi. Pridelava konoplje z veliko vsebnostjo CBD ali CBG in majhno vsebnostjo THC predstavlja velik izziv, ki se začne že pri izbiri sorte. Sorte industrijske konoplje, katerih namen pridelave je za seme in stebla, običajno vsebujejo manj kanabinoidov v socvetjih. Medtem ko feminizirane sorte (to so sorte, katerih seme je samo ženskega spola), ki so bile požlahtnjene z namenov pridelave kanabinoidov in vsebujejo visoke vsebnosti CBD ali CBG v socvetjih, lahko vsebujejo višje vsebnosti THC od z zakonom dovoljenih. Prav tako te sorte v naših rastnih razmerah običajno dozorevajo pozneje, na EU sortni listi pa jih je malo. Namen raziskave je bil primerjati različne sorte industrijske konoplje za namene pridelave kanabinoidov, pri čemer nas je najbolj zanimal pridelek zelene biomase (socvetja z listi) in vsebnost kanabinoidov v njej.
V poskusu smo uporabili 10 sort, in sicer 'Northwest', 'Midwest', linija 'CBGo' in 'Enectaliana', ki so feminizirane, ter 'Carmagnola', 'Dioica 88', 'Fibranova', 'Kompolti', 'Tiborszallasi' in 'Elleta Campana', ki so dvodomne. Ženske rastline smo gojili v rastni sezoni leta 2023 v okolici Krškega, pri gostoti 1 rastlina na m^2. Pri polovici rastlin vsake sorte smo po dveh tednih rasti na njivi izvedli ukrep vršičkanja (odstranitev glavnega poganjka). Med rastno dobo smo nabrali po 30 listov na sorto za podatke o površini listov, številu lističev in širini glavnega lističa. Po žetvi (konec septembra in v oktobru) smo rastline ločili na stebla in socvetja z listi ter jih stehtali pred in po sušenju. Vsebnosti kanabinoidov v suhih socvetjih z listi smo merili s tehniko visoko ločljivostne tekočinske kromatografije (HPLC) in z napravo GemmaCert (NIRS tehnologija).
Rezultati so pokazali, da vršičkanje ni imelo vpliva na končno višino rastlin, je pa povzročilo večji pridelek suhih socvetij z listi pri večini sort. Ugotovili smo, da merjenje vsebnosti kanabinoidov v socvetjih z listi z napravo GemmaCert ni natančno, saj v vzorcih v primerjavi s tehniko HPLC pokaže preveč THC in premalo CBD v primerjavi s tehniko HPLC. Vse tri feminizirane sorte za namen pridelave CBD so imele najvišje vsebnost skupnega CBD v socvetjih z listi (od 6,5 do 14,3 %), medtem ko so imele dvodomne sorte manjše vsebnosti. Linija 'CBGo' je pričakovano vsebovala največ kanabinoida CBG (6,8 %). Največji pridelek CBD v suhih socvetjih z listi so dosegle vršičkane rastline sorte 'Midwest' (42,5 g na rastlino), največji pridelek CBG pa vršičkane rastline linije 'CBGo' (32,0 g na rastlino). Sorte so se razlikovale tudi po morfometriji listov: feminizrane sorte so imele v povprečju manjšo površino listov in list sestavljen iz manjšega števila lističev kot dvodomne sorte. Najširši glavni listič je imela linija 'CBGo' (48,97 mm), medtem ko med ostalimi sortami ni bilo večjih razlik. Lastnosti listov niso bile povezane z vsebnostjo kanabinoidov.

Ključne besede: industrijska konoplja, sorte, kanabinoidi, morfološke lastnosti rastlin

[40] Doc. dr., Biotehniška fakulteta, Oddelek za agronomijo, e-pošta: marko.flajsman@bf.uni-lj.si

Suitability of dioecious and feminized industrial hemp varieties for cannabinoid production

Industrial hemp (*Cannabis sativa* L.) is a versatile plant that has been used in medicine, food and fibre production for thousands of years. Its cultivation is regulated by law due to the psychoactive cannabinoid THC (Δ9-tetrahydrocannabinol). CBD (cannabidiol) and CBG (cannabigerol) are not psychotropic cannabinoids, but they have significant therapeutic benefits, which have been confirmed for CBD in particular, and new research is also showing the positive effects of CBG on human health. Growing hemp with a high CBD or CBG content and a low THC content is a major challenge, starting with the selection of the variety. Industrial hemp varieties, which are designed to produce seeds and stems, tend to contain less cannabinoids in the inflorescences. Feminised varieties (i.e. varieties whose seeds are only female) which are bred for cannabinoid production and have a high level of CBD or CBG in the inflorescences, can have higher THC level than legally permitted. But such varieties also tend to mature later under our growing conditions and there are only a few of them on the EU variety list. The aim of the research was to compare different varieties of industrial hemp for cannabinoid production, with the main interest being the yield of green biomass (inflorescences with leaves) and the cannabinoid content therein.

Ten varieties were used in the trial, namely 'Northwest', 'Midwest', the line 'CBGo' and 'Enectaliana', which are feminized, and 'Carmagnola', 'Dioica 88', 'Fibranova', 'Kompolti', 'Tiborszallasi' and 'Elleta Campana', which are dioecious. Female plants were grown during the 2023 growing season near Krško at a density of 1 plant per m2. Half of the plants of each variety were topped (removal of the main shoot) after two weeks of growth in the field. During the growing period, 30 leaves per variety were collected to obtain data on the leaf area, the number of leaflets and the width of the main leaflet. After harvest (end of September and in October), the plants were separated into stems and inflorescences with leaves and weighed before and after drying. The cannabinoid content in the dried inflorescences with leaves was measured using high performance liquid chromatography (HPLC) and the GemmaCert device (NIRS technology).

The results showed that topping had no effect on the final height of the plants, but resulted in a higher yield of dry inflorescences with leaves in most varieties. We found that measuring cannabinoid content in inflorescences with the GemmaCert device is not accurate as it shows too much THC and too little CBD in the samples compared to the HPLC technique. All three feminised varieties for CBD production had the highest levels of total CBD in the inflorescences with leaves (from 6.5 to 14.3%), while the dioecious varieties had lower levels. As expected, the 'CBGo' line contained the most cannabinoid CBG (6.8%). The highest CBD yield in dry inflorescences with leaves was achieved by the topping plants of the 'Midwest' variety (42.5 g per plant), while the highest CBG yield was achieved by the topping plants of the 'CBGo' line (32.0 g per plant). The varieties also differed in leaf morphometry: on average, feminised varieties had a smaller leaf area and a leaf consisting of fewer leaflets than dioecious varieties. The line 'CBGo' had the widest main leaflet (48.97 mm), while there were no significant differences between the other varieties. Leaf characteristics were not related to cannabinoid content.

Keywords: hemp, varieties, cannabinoids, morphological characteristics of plants


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