BOOK OF ABSTRACTS

CROPINNO Final Conference

“New Approaches in Crop Improvement for Increased Climate Resilience”

26 June 2025

Novi Sad, Serbia

CROPINNO Final Conference

"New Approaches in Crop Improvement for Increased Climate Resilience"

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ISBN 86-86221-02-5

https://fiver.ifvcns.rs/handle/123456789/5445

Published by the Institute of Field and Vegetable Crops, National Institute of the Republic of Serbia.

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SECTION 1

SOIL AND CLIMATE

CLEARCLIMATE: PROVIDING CLEARER CLIMATE INFORMATION SERVICES FOR RESILIENT AND SUSTAINABLE CROP PRODUCTION

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ClearClimate is an interdisciplinary research and innovation network designed to overcome the most critical barriers to the uptake of Climate Information Services (CIS), including lack of understanding, trust, relevance, actionable insights, and incentives. These challenges are especially prominent in South-Eastern Europe (SEE), where climate services remain underutilised despite growing exposure to climate extremes such as droughts and heatwaves—most notably the record-breaking summer of 2024 in the Balkans. Recognizing the urgent need for localised and demand-driven solutions, ClearClimate aims to co-create tailored CIS that address the unique agricultural, socio-political, and environmental conditions in the region. By integrating state-of-the-art climate science with social science, human-centred design, explainable artificial intelligence (XAI), and advanced data visualisation, ClearClimate advances a new generation of CIS focused on practical usability for end users, particularly in agriculture. The project develops frameworks for human-centred CIS, enhances interpretability using XAI, and leverages real-time data to support farm-level decision-making. These innovations are crucial for enabling sustainable crop production in an increasingly variable climate. The project placed much focus on storytelling, eye-tracking, and neuromarketing, providing actionable insights into how different formats of climate communication influence farmers' understanding, trust, and engagement. Cultural adaptation of messages ensures relevance and accessibility, especially for vulnerable or underserved populations. The network's activities—spanning co-design, AI-enhanced analysis, psychophysiological testing, and user training—support long-term transformation by building local capacity and fostering cross-sector collaboration. Ultimately, ClearClimate contributes to sustainable crop production by aligning climate information with farmers' realities, thereby enabling climate-smart agricultural practices. It not only bridges the gap between science and society but also empowers agricultural stakeholders in the SEE region to adapt effectively to climate change, promoting both resilience and food security in a region at the forefront of climate vulnerability.

Keywords: Climate Information Services (CIS), sustainable crop production, Explainable Artificial Intelligence (XAI), climate-smart agriculture, user-centered design

ADVANCING SUSTAINABLE SOLUTIONS FOR CONTAMINANTS IN SOIL WITH CARBON-BASED AMENDMENTS

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Contaminated environmental matrices, particularly soils and sediments, continue to pose significant threats to ecosystem health, human safety, and the sustainability of land and water resources. This study explores the effectiveness of organic and carbon-rich amendments, including biochar, hydrochar, and compost-based materials, in reducing the risks associated with diverse organic pollutants. Controlled laboratory experiments indicate that these amendments enhance the sorption of contaminants by altering the physical and chemical characteristics of the matrices, thereby limiting pollutant mobility and bioavailability. This immobilization reduces the potential for groundwater contamination and uptake by biota. Furthermore, certain amendments promote microbial activity that facilitates the degradation of specific organic compounds, contributing to in situ natural attenuation processes. The research highlights how amendment properties such as porosity, surface area, and chemical structure govern their remediation performance. Mechanistic insights suggest that interactions between pollutants and amendments occur through hydrophobic partitioning, and surface complexation, which together control contaminant fate. Results emphasize the adaptability of these amendments, allowing for their selection and optimization based on the nature of the contamination and site conditions. Importantly, the use of waste-derived materials aligns with principles of sustainable remediation and circular economy by turning organic residues into valuable remediation tools. This work reinforces the potential of carbon-based amendments in improving the environmental safety of polluted matrices and supports their integration into future nature-based remediation frameworks.

Keywords: Environmental remediation, carbon-based amendments, pollutant bioavailability, sorption mechanisms, biodegradation, sustainable remediation

Acknowledgements: Funded by the European Union. Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union or European Research Executive Agency (REA). Neither the European Union nor the granting authority can be held responsible for them. Grant agreement No. 101059546.

ADVANCED ANALYTICAL AND TREATMENT STRATEGIES FOR EMERGING WATER POLLUTANTS: BUILDING INSTITUTIONAL CAPACITY IN THE CONTEXT OF THE TRIPLE PLANETARY CRISIS

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The Horizon Europe project TwiNSol-CECs (GA 101059867) aims to enhance the research excellence of the Faculty of Technology Novi Sad in the field of environmental contaminants of emerging concern (CECs) by fostering the institutional capacities through knowledge transfer, training, and scientific collaboration. Various CECs, including pharmaceuticals, pesticides, personal care products, PFAS, industrial chemicals, etc. represent a growing environmental concern due to their uncontrolled release, potential persistence, mobility, and bioaccumulation, as well as insufficient monitoring and regulation. In response, TwiNSol-CECs promotes state-of-the-art analytical methods for CECs detection (e.g. ultra high-performance liquid chromatography with high-resolution mass spectrometry) and evaluates innovative removal technologies such as adsorption-based treatments involving biomaterials, and advanced oxidation processes. These efforts are embedded in a broader vision of addressing the triple planetary crisis, climate change, pollution, and biodiversity loss, by contributing to the protection of water resources, ecosystem health, and public safety. Beyond scientific innovation, the project emphasizes the development of human and infrastructural capacities in less research-intensive regions, supporting long-term institutional resilience and cross-border scientific networks in the Western Balkans and EU. By integrating environmental science, technology, and capacity building, TwiNSol-CECs exemplifies a holistic approach to sustainable environmental management.

Keywords: emerging contaminants, water, advanced monitoring, removal technologies, Serbia

Acknowledgements: Funded by the European Union. Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union or EU executive agency. Neither the European Union nor the granting authority can be held responsible for them. This work is conducted under the project TwiNSol-CECs that has received funding from Horizon Europe programme under grant agreement no.101059867.

SECTION 2

BREEDING FOR RESILIENCE

STATUS OF BREEDING AND SEED PRODUCTION OF MAJOR FIELD CROPS IN SERBIA: FACING THE EFFECTS OF CLIMATE CHANGE

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Serbia has favorable agro-ecological conditions for crop production, especially for field crops such as maize, wheat, sunflower, soybean etc. With a long tradition in plant breeding and seed production, the country holds strong potential for developing a competitive seed industry. However, climate change, through higher temperatures, shifting rainfall patterns, and more frequent extreme weather, poses serious challenges to traditional crop varieties, affecting both yield and quality. Breeding programs should focus on traits like drought and heat tolerance, and resistance to pests and diseases. Modern tools such as molecular breeding and advanced seed technologies need to be more widely applied to speed up the development of climate-adapted varieties. To maintain productivity and ensure food security amid a changing climate, Serbia must adopt clear policies and significantly increase investment in agricultural research and development to strengthen its breeding and seed systems.

Keywords: field crops, plant breeding, seed industry, Serbia

Acknowledgements: This work is supported by the Ministry of Science, Technological Development and Innovation of the Republic of Serbia, grant number 451-03-136/2025-03/ 200032, by the European Commission through Twinning Western Balkans project CROPINNO, grant number 101059784, by Center of Excellence for Innovations in Breeding of Climate-Resilient Crops - Climate Crops, Institute of Field and Vegetable Crops, Novi Sad, by Women Netting for Seed Treasure Revival – NEST (2024–2026), grant no. 1377/24. funded by the Center for the Promotion of Science.

SNP-BASED MARKERS FOR DROUGHT TOLERANCE IN SUNFLOWER

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Developing SNP-based markers, such as KASP, HRM and STARP, from RNASeq data is a quick and effective method to support marker-assisted breeding for drought tolerance in sunflower. RNASeq reads (150 bp PE, 12 Gb raw data per sample) from the two sunflower cultivars DF-AB-2 and AB-OR-8 were mapped to the sunflower reference genome HanXRQr2.0. The SNP calling with GATK 4.1.4.1 and SNP annotation with SnpEff resulted in a total of 3,021,255 SNPs over all samples. Perl scripts were used to compare SNPs from the two cultivars and to receive SNPs that are only present in DF-AB-2 or AB-OR-8, but not in both. With this procedure, 64,098 SNPs were identified for DF-AB-2, while in AB-OR-8 only 37,092 SNPs were observed in comparison to HanXRQr2.0. To get an overview of the SNPs, density plots for each chromosome were created for both cultivars. The list of SNPs will be further used to develop markers in a set of candidate genes involved in ABA biosynthesis and signalling pathway. SNPs that lead to missense mutations are most interesting for marker developments, because the mutations might have an influence on the protein responsible for a trait. The putative beta-carotene 3-hydroxylase (HanXRQr2_Chr15g0719741) on chromosome 15 is part of the ABA biosynthesis. The gene shows two SNPs at position 168,965,031 bp and 168,965,042 bp. These SNPs leading to missense mutations are present in all RNAseq samples (tissues and treatments) of the cultivar AB-OR-8, but not in the cultivar DF-AB-2. The next step is to design primers e.g. for KASP markers in order to associate the SNPs with drought tolerance. With the presence of the SNP in only one cultivar, KASP markers can be used and tested in an association panel of 100-200 sunflower genotypes, which has been screened for drought tolerance. KASP markers associated with drought tolerance can then be used for marker-assisted selection in sunflower breeding programs in order to breed for climate resilient cultivars.

Keywords: SNP-based markers, RNASeq, KASP, whole genome SNP analysis, drought tolerance

Acknowledgements: We are grateful to the breeders of the IFVCNS for providing the sunflower seeds. We would also like to thank the EU for funding HORIZON Europe project CROPINNO, grant number 101059784.

REACTION OF SUNFLOWER MATERIAL FROM IFVCNS TO *O. cumana* RACE F AND A SENSOR-BASED INITIAL APPROACH FOR EARLY DETECTION OF INFECTIONS

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Broomrape, caused by the root parasitic plant Orobanche cumana Wallr., is one of the main biotic constraints on sunflower oil production. Parasite races A to F, with increasing levels of virulence, have been described. These are controlled by incorporating resistance genes into the hybrids. The IFVCNS has an important collection of sunflower lines in its breeding program. These lines respond differently to biotic and abiotic stresses and are intended to obtain sunflower hybrids with resistance to broomrape race F eventually. According to previous research by our group, broomrape infections can be detected by multicolor fluorescence measurements under specific temperature conditions and in darkness. Additionally, symptoms of crop diseases caused by pathogens other than *O. cumana* can be detected through spectral indicators before visual symptoms appear. Our objectives were to: i) evaluate the reaction of IFVCNS entries to *O. cumana* race F, and ii) assess the effectiveness of different sensors for early infection detection. A greenhouse experiment was conducted from February to May 2025. Sixteen sunflower lines, along with control lines B117 (susceptible to all races) and NR5 (susceptible to race F, resistant to races <F), were included, using the *O. cumana* race F population Oc0115. Six individual seedlings (replications) of each genotype were inoculated by transplant to broomrape-infested soil and grown in a greenhouse at 23–27°C with a 14-hour photoperiod. Control plants were transplanted to non-infested soil and maintained under the same conditions. The number of emerged *O. cumana* stems per plant was assessed weekly until sunflower senescence. Nine weeks after inoculation (WAI), broomrape incidence (BI, percentage of sunflower plants with broomrape) and final degree of attack (FDA, number of nodules and stems per plant) were recorded. Genotype AZDO-2 was as susceptible as B117: FDA=1.5 nodules and stems/plant and BI=83%. Genotypes AB-OR-8, AR-KOR-5, BG-N-2, IMI-AB 24-PR, NS-KOD-4-PR-SU, and OD-DI-65-SU showed moderate susceptibility (averages FDA=0.3 nodules and stems/plant, and BI=22%). The remaining nine genotypes were resistant to the parasite. During the initial weeks of the experiment, up to 5 WAI (when parasite stems emerged aboveground), several devices were used to take weekly measurements on B117 and NR5 control and inoculated plants: porometer, fluorometer, spectrophotometer, and optical sensors to assess flavonoid, anthocyanin, and chlorophyll contents in leaves. Measurements were taken at the same time of day on shaded leaves. For each treatment, one leaf from each of the six plants was measured. Very low standard deviations in the averages confirmed that the protocol was robust and replicable. In our greenhouse conditions, the most effective devices for infection detection were those measuring chlorophyll fluorescence, leaf temperature, stomatal conductance, NDVI, and anthocyanin content. Infected plants also exhibited higher hyperspectral signature values.

Keywords: genetic resistance, phenotyping, proximal sensing

Acknowledgements: CROPINNO Project and Climate Crops Center of Excellence GA Project 101059784 (Horizon Europe Widera 2021 Programme), QUAL21-023_IAS (Junta de Andalucía), and 202240E029, 202240E092, 202340E105 (CSIC).

SUNFLOWER BREEDING STRATEGIES TO OVERCOME CLIMATE-INDUCED AGRICULTURAL CHALLENGE

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Climate change presents a growing challenge to global agriculture, with increasing temperatures, shifting precipitation patterns, and more frequent extreme weather events threatening crop productivity and stability. Sunflower (*Helianthus annuus* L.), one of the key oilseed crops, exhibits substantial adaptability to various agroecological conditions but remains vulnerable to combined and sequential climate-induced stresses, such as drought, heat, and soil degradation. These stresses can significantly reduce seed and oil yield, disrupt developmental phases, and impact overall crop quality. To ensure sunflower remains a resilient and productive crop under future climate scenarios, breeding efforts must focus on enhancing tolerance to a wide range of abiotic stresses. This requires a deeper understanding of genetic diversity, physiological responses, and the molecular mechanisms underlying climate resilience. Integrating advanced "omics" technologies such as genomics, phenomics, transcriptomics, proteomics, metabolomics, and epigenomics enables the identification of key adaptive traits and accelerates the development of climate-resilient genotypes. High-throughput, non-invasive phenotyping tools, especially those targeting root traits, stress physiology, and growth dynamics, offer valuable insights into sunflower responses under variable conditions. By combining genetic resources, cutting-edge technologies, and targeted selection strategies, breeding programs can develop sunflower hybrids capable of sustaining yield and quality in the face of intensifying climate challenges, thereby contributing to more resilient agricultural systems.

Keywords: sunflower, drought, omics-, yield, root traits

Acknowledgements: This work is supported by the Ministry of Science, Technological Development and Innovation of the Republic of Serbia, grant number 451-03-136/2025-03/ 200032, by the Science Fund of the Republic of Serbia through IDEAS project "Creating climate smart sunflower for future challenges" (SMARTSUN), grant number 7732457, by the European Commission through Twinning Western Balkans project CROPINNO, grant number 101059784, by Center of Excellence for Innovations in Breeding of Climate-Resilient Crops - Climate Crops, Institute of Field and Vegetable Crops, Novi Sad, by Horizon Europe HelEx N°101081974 funded by the European Commission Serbia, by bilateral cooperation project between the Republic of Serbia and Turkey 2024-2026 - Development of CRISPR-mediated resistance to fungal diseases in sunflower (Helianthus annuus), grant number 0260207, financed by The Ministry of Science, Technological Development and Innovations of the Republic of Serbia (NITRA) and The Scientific and Technological Research Council of Turkey (Tübitak), and based upon work from COST Action RECROP (CA22157) COST (European Cooperation in Science and Technology). www.cost.eu.

CONTRIBUTION TO LEGUME BREEDING ON EUROPEAN LEVEL: BELIS PROJECT

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The legume industry requires improved varieties tailored to various regions and applications to address identified challenges. The EU-funded BELIS project (2023-2028) aims to enhance competitiveness in legume breeding by refining methodologies and governance structures. Additionally, it facilitates the transfer of genetic advancements to industry players and farmers, ultimately boosting biodiversity and ecosystem services. The project is focused on seven forage legumes and seven grain legumes that are currently grown to produce feed (for ruminants – cattle, sheep, goat and monogastric animals – pig, poultry), food (as is or after processing) or to deliver ecosystem services. BELIS team is actively developing cost-effective breeding programmes and tools, providing breeders with proofs of concept, and navigating economic and regulatory environments. Within the scope of the project, IFVCNS is developing protocols for abiotic stresses, working on phenotypic and molecular breeding as proofs of concept and contributing to the variety recommendation on EU level for various legume crops. As part of the collaborative efforts to highlight how Value for Cultivation and Use (VCU) tests and protocols could be improved in several partner countries in Europe, the project contributes to the study and comparison of existing VCU trial methodologies. Comprehensive data were collected from technical questionnaires regarding trial setups, operational or cultivation practices, and traits currently monitored in VCU testing across Europe. These data were supplemented by the identification of additional traits to improve the performance assessment of new legume varieties on EU level.

Keywords: soybean, alfalfa, pea, chickpea, VCU, breeding tools

Acknowledgements: This research was supported by the project BELIS "Breeding European legumes for increased sustainability" which received funding from the Horizon Europe research and innovation programme under the Grant Agreement N°101081878.

SECTION 3

OMICS TOOLS

axiomFP.py A SOFTWARE FOR VISUAL PLOIDY AND QUALITY ASSESSMENT OF AXIOM SNP ARRAY DATA

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axiomFP.py is an open-source software developed to diagnose ploidy level and call quality for samples genotyped on Affymetrix Axiom SNP arrays by making frequency plots of normalized SNP call positions among SNPs meeting specific clustering parameters. This research outlines the methods employed in the development of the software, and presents the results obtained through its application on a dataset of mixed ploidy apple (*Malus* spp.) cultivars and germplasm accessions. The tools required to prepare the input files and operate the software are also described. The frequency plots generated by the software require a visual inspection to assess ploidy and call quality. The results have been validated using the available ploidy data, as well as flow cytometry, and have shown complete accuracy. The software is available on GitHub at https://github.com/allmiraria/axiomFP.

Keywords: Axiom, genotyping, frequency plots, call quality

SEEING THE UNSEEN: ADVANCED IMAGING APPROACHES IN PLANT STRESS RESEARCH

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In the quest to enhance crop resilience and productivity under stress conditions, imaging-based high-throughput phenotyping (HTP) emerges as a powerful ally, capable of detecting early physiological responses before visible symptoms appear. This lecture draws on technologies such as thermal, multispectral, hyperspectral imaging, X-ray CT, and chlorophyll fluorescence, which serve as "superpowers" in modern plant science. By showcasing selected examples from recent research on nutrient deficiency, salinity, drought, and herbicide-induced stress, we demonstrate how imaging-derived traits (e.g. canopy temperature, reflectance indices, PSII efficiency, plant/organ architecture) provide deep insights into plant performance under different stresses. Furthermore, we discuss the integration of these tools with machine learning and automated analysis pipelines, revealing their role not only in physiological research but also in accelerating breeding decisions. Imaging phenotyping delivers fast, precise, and scalable information crucial for facing today's agricultural challenges.

Keywords: high-throughput phenotyping, imaging technologies, early stress detection, chlorophyll fluorescence, spectral analysis

PHENO-DROP PROJECT – ADVANCING DROUGHT RESILIENCE IN BREAD WHEAT THROUGH GENOMICS AND PHENOMICS INNOVATIONS

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Bread wheat is a vital rainfed crop in both Italy and Serbia, where climate change has led to an increased frequency of droughts and extreme weather events, presenting serious threats to yield and yield stability. Traditional breeding approaches have achieved limited success in improving drought tolerance due to the complex, low-heritability nature of this trait and strong genotype-by-environment interactions. The project "New PHENO-ideotypes for DROught resilience in hexaPloid wheat – PHENO-DROP", supported by the Ministry of Science, Technological Development and Innovation of the Republic of Serbia, under the Call for Joint Research and Innovation Projects 2024–2026 between Italy and Serbia, aims to address these challenges. The main focus of this bilateral project is to strengthen scientific excellence and innovation capacities through the exchange of practical and theoretical knowledge between research institutions in Italy and Serbia to improve hexaploid wheat breeding for drought conditions. PHENO-DROP integrates high-throughput phenomics, genomics, and bioinformatics to explore and validate drought-resilient pheno-ideotypes in a diverse panel of hexaploid wheat germplasm, including both landraces and modern bread wheat varieties. The project focuses on key traits related to Water Use Efficiency (WUE), such as root architecture, stomatal characteristics, osmotic adjustment, and canopy-level indices. It will assess genetic variability within wheat landraces to identify phenotypic traits, key genes, and regulatory mechanisms underlying water scarcity tolerance. Additionally, it will evaluate yield stability and identify associated phenotypic traits in a panel of modern Serbian and Italian wheat varieties across diverse environments. These outcomes will foster innovation in breeding approaches and support sustainable wheat production in drought-prone regions of the pan-Adriatic zone.

Keywords: bread wheat, climate resilience, genetic resources, grain yield, gene expression

Acknowledgements: This research was supported by the Ministry of Science, Technological Development and Innovation of the Republic of Serbia, grant number: 451-03-136/2025-03/ 200032, project PHENO-DROP – New PHENO-ideotypes for DROught resilience in hexaPloid wheat - Call for joint research and innovation projects 2024-2026 in the framework of the memorandum of understanding on cooperation in the fields of higher education, research and innovation between Italy – Serbia, and Centre for Innovation in Breeding of Climate-Resilient Crops – Climate Crops of Institute of Field and Vegetable Crops, Novi Sad, Serbia

INTRODUCING TRANSCRIPTOMICS IN IFVCNS SUNFLOWER BREEDING PROGRAM

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Sunflower is one of the most important oil crops globally and the leading oil crop in Serbia. In 2024, FAO ranked Serbia among the top 10 countries with the highest sunflower seed production, highlighting the significance of sunflower breeding. Over the past six decades, the Institute of Field and Vegetable Crops (IFVCNS) has developed thousands of diverse sunflower lines and hybrids, continuously refining its breeding program. The IFVCNS breeding program follows multiple strategic directions, with a primary focus on developing high-yielding, high-quality sunflower lines and hybrids. Climate change has increasingly impacted breeding programs, prompting a faster the need for a more rapid approach to gene and trait discovery. One of the most critical abiotic stressors affecting sunflower production is drought, which significantly reduces yield and quality, particularly during germination and flowering. Among omics techniques, transcriptomics has proven invaluable in identifying key pathways and genes associated with drought tolerance. To address this challenge, two IFVCNS sunflower inbred lines—one drought-tolerant and one drought-sensitive—were subjected to drought stress, and their transcriptomes were analyzed. This research aims to uncover major drought-tolerance candidate genes that could be integrated into future breeding programs to enhance sunflower resilience

Keywords: Helianthus annuus, RNASeq, gene mining, drought tolerance, climate change

Acknowledgements: This work is supported by the Ministry of Science, Technological Development and Innovation of the Republic of Serbia, grant number 451-03-136/2025-03/ 200032, by the Science Fund of the Republic of Serbia through IDEAS project "Creating climate smart sunflower for future challenges" (SMARTSUN), grant number 7732457, by the European Commission through Twinning Western Balkans project CROPINNO, grant number 101059784, by Center of Excellence for Innovations in Breeding of Climate-Resilient Crops - Climate Crops, Institute of Field and Vegetable Crops, Novi Sad, by Horizon Europe HelEx N°101081974 funded by the European Commission Serbia, by bilateral cooperation project between the Republic of Serbia and Turkey 2024-2026 - Development of CRISPR-mediated resistance to fungal diseases in sunflower (Helianthus annuus), grant number 0260207, financed by The Ministry of Science, Technological Development and Innovations of the Republic of Serbia (NITRA) and The Scientific and Technological Research Council of Turkey (Tübitak), and based upon work from COST Action RECROP (CA22157) COST (European Cooperation in Science and Technology). www.cost.eu.

SOYBEAN YIELD PREDICTION USING MULTI-OMICS DATA INTEGRATION

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SoyPredict focuses on the efficiency improvement of breeding new soybean varieties, suitable for Serbian and European agro-climatic conditions, by applying advanced breeding tools, multi-omics data and advanced mathematical modeling for yield prediction. Project activities are focused on soybean, as crop of major economic and environmental importance, by developing long-term breeding strategies based on state-of-the-art technologies. The term 'breeding strategy' implies a plan to optimize the production of soybean varieties using the full suite of technologies and to release improved cultivars faster. Specific strategies will determine how to integrate traditional and multi-omics approaches for improving the efficiency of breeding process. Main concept of SoyPredict is predicting ability and accuracy of GP, HTPP and PP models in soybean yield prediction (within and between environments, in different stages of genotype evaluations), implementing model compilation and developing strategy for model/models application in cost effective manner. Degree and relations between yield predictors are complex (and probably non-linear), while SoyPredict have ambition to estimate efficiency of each particular model and describe mutual relationships. For prediction model compilations, SoyPredict will use several strategies. First one is treating equally all data sets (SNP, NIR, HTTP). Linear mix models and its variation is first choice in phenotype prediction for complex traits. At their core, those models rely at the assumption that genetically similar individuals are more likely to share similar phenotypes. Recently, high-order interaction linear mix models show promising results. Using all mentioned strategies for combining prediction models should provide answer is it possible to improve precision and accuracy of soybean phenotype prediction, within and between environments, as key indicator for increasing the genetic gain.

Keywords: soybean, breeding, prediction models

Acknowledgements: This research was supported by the Science Fund of the Republic of Serbia, 6788, Soybean Yield Prediction Using Multi-Omics Data Integration SoyPredict.

SECTION 4

AGROECOSYSTEM SERVICES

AGROSERV: BUILDING A SUSTAINABLE FUTURE FOR EUROPEAN AGRICULTURE

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AgroServ is a European Union-funded project (Horizon Europe) that supports the transition to sustainable and resilient agriculture through agroecology. Running from 2022 to 2027, it brings together 73 partners across Europe and offers researchers free access to a wide range of scientific services and infrastructures. The project aims to address major challenges such as climate change, biodiversity loss, soil degradation, and sustainable food production by promoting multidisciplinary research and collaboration. AgroServ integrates services in fields like biology, ecology, data science, and socio-economics, and encourages stakeholder engagement through living labs and co-creation processes. A key goal is to develop a federated data infrastructure that supports FAIR principles and long-term knowledge sharing. By enabling holistic research and innovation, AgroServ contributes to shaping evidence-based policies and advancing sustainable farming systems across Europe. The Institute of Field and Vegetable Crops in Novi Sad (IFVCNS) is one of the partners in AgroServ. With its long tradition in crop breeding, seed production, microbiology, agrochemistry, and extensive field trial capacities, IFVCNS contributes valuable expertise in sustainable crop systems. Their engagement strengthens AgroServ's efforts in integrating practical, field-based research and farmer collaboration into the broader agroecological transformation across Europe. In the first two calls for transnational access (TA) projects, IFVCNS and its service Plant&Soil_Pheno were present in 4 submitted proposals, from which 3 were approved. So far, one of these projects was completed, the second is in the progress and the third will be started during the autumn 2025. The completed project Novel Biodiversity assessment Technologies for determination of Arthropods and Pollinators in Sunflowers, BioTechAPS, was focused on using advanced molecular tools to evaluate biodiversity in sunflowers, particularly in relation to drought-resistant hybrids. It contributed to understanding of how farming practices influence biodiversity, ultimately supporting the development of stable and healthy food systems.

Keywords: agroecology, sustainability, research infrastructure, TA projects, IFVCNS

Acknowledgements: This work was supported by the EU funded project AgroServ GA 101058020. AKŠ, DT, SG, IV, DM, AMJ, ŽM and SG were also supported by the Ministry of Science, Technological Development and Innovation of the Republic of Serbia, grant number 451-03-136/2025-03/ 200032 and by Center of Excellence for Innovations in Breeding of Climate-Resilient Crops - Climate Crops, Institute of Field and Vegetable Crops, Novi Sad, Serbia.

VALORIZATION LEGUMES RELATED AGROSYSTEM SERVICES

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VALERECO aims to accelerate the adoption and recognition of legume crops as key drivers in the shift toward sustainable, productive, climate-resilient, and environmentally friendly farming systems. By assessing both the environmental and economic contributions of ecosystem services (ES) provided by eight major and four minor or underutilized legume species, the project supports greater crop diversification across the EU and associated countries. This diversification is expected to contribute to healthier diets and enhanced climate resilience. The project's analytical framework includes a comprehensive review of ecosystem service legacies and an exploration of entry points for integrating legumes and their associated services into the evolving Common Agricultural Policy (CAP). To put this into practice, VALERECO will establish nine Living Labs across Europe to: (1) design behavioral strategies that promote legume uptake in both production and consumption, (2) conduct participatory field trials to evaluate legume performance in diversified systems, and (3) co-develop technical solutions that are both economically and environmentally viable. The project's results will be widely disseminated through the creation of a Digital Legume Information Hub (DLIH), a Decision Support System (DSS) for farmers and advisors, and an open-access E-learning Platform for capacity building.

Keywords: legumes, ecosystem services, living labs

Acknowledgements: This research was supported by the Ministry of Science, Technological Development and Innovations of the Republic of Serbia, grant number: 451-03-136/2025-03/200032 and by the project VALERECO "Valorization Legumes Related Ecosystem Services which received funding from the Horizon Europe programme under the Grant Agreement N°101135472. DM was also supported by Center for Innovations in Breeding of Climate-Resilient Crops – Climate Crops of Institute of field and Vegetable Crops, Novi Sad, Serbia.

ACTIVE ROLE OF IFVCNS IN ACHIEVING ECOLOGICAL RESILIENT DYNAMISM FOR THE EUROPEAN FOOD SYSTEM THROUGH CONSUMER-DRIVEN POLICIES, SOCIO-ECOLOGICAL CHALLENGES, BIODIVERSITY, DATA-DRIVEN POLICY, SUSTAINABLE FUTURES

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The EU-funded ECO-READY project will ensure that European farmers and society interests are reflected in future policymaking and monitoring with its real-time surveillance system. ECO-READY develops a central digital infrastructure (Observatory) that aggregates all existing data, models and knowledge on food security in the context of impact of climate change on agro-biodiversity and invasive species and genetic resources, sustainable productivity, animal and plant diseases and nutritional composition. The platform will include policy recommendations, contingency plans and resilience strategies developed by 10 Living Labs and provide real-time assessments for the food system, with forecasts updated frequently and consistently. ECO-READY will ensure the European society ‘s interests to be reflected in future policy making and monitoring, having them actively engaged to shaping policy recommendations from an early stage. That will be facilitated by the knowledge communicated via the digital observatory, especially through the smart phone app, increasing their awareness for climate-adaptive and mitigating agri-food products, and enabling them to become users of the tools that will be developed. Main IFVCNS active role was contribution to scenario development that explores agricultural practices, policy changes, innovative farming ideas, and consumer-producer interactions to help mitigate future shocks. The 10 Eco-Ready living labs covering most of geo-climatic zones in Europe have selected key drivers for their food priorities specific to their regions. The scenario development team, consisting of interdisciplinary teams of specialists, together with the living labs representatives, developed five scenarios for each of the ten living labs, resulting in a total 50 scenarios. Given that each of the living labs have customized scenarios relevant to their region, there are various similarities among the living labs, either through shared drivers, products, or interventions.

Keywords: scenario development, biodiversity, climate change, food security

Acknowledgements: This research was supported by the project ECO-READY, European Union's HORIZON-CL6-2022 research and Innovation programme under grant agreement n° 101084201.

SECTION 5

FUTURE TRENDS

LOCAL SEEDS, GLOBAL TOOLS, AND THE FIGHT AGAINST CLIMATE CHANGE

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In the face of climate change, the conservation and sustainable use of plant genetic resources, especially local seeds, have become more critical than ever. These germplasms, adapted over centuries to specific environments, represent a treasure trove of genetic diversity essential for resilient agriculture. The leading research institution dedicated to the study, conservation, and sustainable use of genetic resources in Bosnia and Herzegovina is the Institute of Genetic Resources. Within the institute, there is a Gene Bank with a large seed collection. A large part of the collection has been characterized morphologically, biochemically, and molecularly. Many of the unique accessions have shown specific traits that could be utilized in breeding programs. Traditional breeding takes a long time to produce results. For this reason, mutation breeding has increasingly been used in these activities over the past few decades. Based on prior research, selected unique accessions of common bean and wheat from the Gene Bank were used to initiate mutation breeding, a method that had not previously been applied in Bosnia and Herzegovina. The main goal of this research was to obtain lines/varieties that are resistant to climate change, especially drought as well as to increase their yield. In cooperation with the International Atomic Energy Agency, 6 000 seeds of wheat and common bean have been irradiated. Bean seeds were irradiated with doses of 80 Gy and 200 Gy, while wheat seeds were irradiated with 150 Gy, 200 Gy, and 300 Gy. The germination rates of irradiated seeds were lower at higher radiation doses. Over the course of three years of research, the third mutant generation of the seeds was obtained. Some of the mutant seeds have exhibited phenotypic mutations, such as the presence of awns, variations in spike color, and differences in seed and flower color, which represent a very important foundation for future research. Genomic testing of the mutants will be conducted in order to detect specific genetic variations induced by irradiation and to better understand the molecular basis of the observed phenotypic traits. This approach will enable the identification of genes or genomic regions associated with improved stress tolerance, yield potential, and other agronomically important characteristics. These results constitute the first preliminary findings of mutation breeding in Bosnia and Herzegovina and are expected to contribute significantly to the development of novel approaches in crop improvement aimed at enhancing climate resilience.

Keywords: resilience, germplasm, mutation breeding, wheat, common bean

Acknowledgements: These results are part of the projects: Enhancing Productivity and Resiliences to Climate Change of Major Food Crops in Europe and Central Asia RER5024 funded by IAEA and Induced mutations in bean selections funded by Ministry of Scientific and Technological Development and Higher Education of Republic of Srpska grant no: 19.032/431-1-48/23.

BREEDING THE UNSEEN & DATA-DRIVEN RESILIENCE: UNLOCKING NATURE'S HIDDEN CODE WITH STATISTICAL PRECISION

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In the face of accelerating climate change and increasing global food insecurity, crop breeding must transcend traditional boundaries. This overview explores the convergence of two powerful paradigms: the hidden genetic potential within underutilized crop diversity, and the transformative role of data-driven statistical methodologies in harnessing it. "Breeding the unseen" refers to the strategic exploration and exploitation of cryptic genetic traits found in landraces, wild relatives, and locally adapted varieties. These characteristics are often overlooked by conventional breeding programs, and yet, are crucial for stress tolerance, resilience, and sustainability. Complementing this, "Data-Driven Resilience" emphasizes the application of statistical precision through phenomics, genomic selection, GWAS, and usage of predictive modeling in order to identify, quantify, and accelerate the expression of these hidden codes within breeding pipelines. By integrating multivariate analysis, advanced bioinformatics, and AI-assisted selection, this approach not only enhances genetic gain under stress environments but also redefines the capacity of plant breeders to predict resilience before it's visible in the field. This synthesis of hidden biodiversity with statistical clarity paves the way for a new era of intelligent breeding: anticipatory, inclusive, and resilient by design.

Keywords: genetic diversity, cryptic traits, data-driven breeding, predictive modeling, climate-resilient crops

SOME RECENT DEVELOPMENTS IN ARTIFICIAL INTELLIGENCE FOR BIOLOGY

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We discuss several illustrative recent developments in artificial intelligence for genetics and pharmacology in order to motivate similar developments in crop improvement. It is generally accepted that year 2012 marked the beginning of the “big bang” of applications of deep learning and deep neural networks to a host of previously unsolvable problems: automated image classification, speech recognition, medical diagnostics, autonomous driving, etc. Today, we call the kind of artificial intelligence that can do various classifications “perceptive AI”. A great representative of recent perceptive AI in biology is the DeepVariant algorithm developed by Google and more recently accelerated by Nvidia scientists. It does germline variant calling, i.e., detects inherited genetic differences such as single nucleotide variants and small insertions or deletions. It does it by transforming the problem into an image classification task, appropriate for convolutional neural networks and by doing that achieves higher accuracy in detecting both SNVs and InDels, and is less prone to false positives compared to traditional statistical methods. In 2017 we witnessed another revolution in artificial intelligence, with various Transformer architectures first applied to automated language translation and then soon to various other translations, from one domain to another, for example from textual description to generated images, from complicated legal documents to generated easy-to-understand summaries, or from a sequence of amino acids forming a protein to its 3D shape that determines its metabolic role. This type of artificial intelligence is now called “generative AI”. With it we are quickly approaching the time when a textual prompt with pharmacological requirements will suffice to generate the structure and the procedure to produce a new medication. We have already seen the generative AI for designing and validating easily synthesizable antibiotics by scientists at Stanford. They created a team of AI agents similar to a team of scientist working on discovering new antibiotics. This team of AI agents was able to design 58 molecules as candidates for antibiotics against *Acinetobacter baumannii*, one of World Health Organization’s three critical priority superbugs. Experimental validation confirmed that six structurally novel molecules demonstrated antibacterial activity against *A. baumannii* and several other phylogenetically diverse bacterial pathogens and are now in clinical studies. We think it is not hard to imagine how the breakthroughs financed by medical science can be applied in adjacent sciences that too can benefit the humanity.

Keywords: artificial intelligence, genetics, pharmacology, crops

Acknowledgements: Nvidia Corporation

NET4DINAR – NEW EMERGING TECHNOLOGIES FOR DIGITALIZED INNOVATIVE AGRICULTURAL RESEARCH

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Agricultural research in the era of climate change requires a strategic shift toward digitalization, automation, and integration of advanced tools for crop monitoring, selection, and yield forecasting. The NET4DINAR project is designed to strengthen institutional capacities for research and innovation in plant breeding by integrating digital technologies, artificial intelligence, and cross-border cooperation. The project is implemented through a partnership between the Institute of Field and Vegetable Crops, Novi Sad, and the Agricultural Institute Osijek, aiming to build a shared research platform and deliver novel technological solutions to support breeding programs under climate stress. Wheat is selected as the model crop due to its agronomic importance and vulnerability to climatic extremes. Key project activities include: i) joint field trials for evaluation of wheat germplasm under varying environmental conditions; ii) implementation of high-throughput phenotyping using UAV-based platforms and sensor technologies for monitoring canopy development; iii) extraction and analysis of vegetation indices (e.g. NDVI, GNDVI, SR) to assess photosynthetic activity and plant vigor; iv) development of AI-powered tools for early yield prediction based on integrated phenotypic, environmental, and climatic data; and v) knowledge transfer through pilot actions and institutional training. These integrative approaches are expected to enhance the selection efficiency for stress-resilient genotypes, shorten breeding cycles, and improve the accuracy of research outputs. The AI-based forecasting platform developed within NET4DINAR will enable real-time assessment of yield potential and stress performance, contributing to the broader goals of sustainable crop production and digital transformation of agriculture. Results and tools generated in wheat will be applicable and transferable to other major crops in the region. The project directly targets research institutions and plant breeders, while indirectly supporting farmers and agricultural sectors across the cross-border area.

Keywords: wheat, digital phenotyping, vegetation indices, artificial intelligence, climate resilience

Acknowledgements: This work was supported by the Interreg VI-A IPA Croatia-Serbia 2021-2027 programme under the project NET4DINAR (HR-RS00038). Part of the research conducted by Milan Mirosavljević and Sanja Mikić was supported through the activities of the Centre of Excellence for Innovations in Breeding of Climate-Resilient Crops - Climate Crops of Institute of field and Vegetable Crops, Novi Sad, Serbia.

CIP - Каталогизација у публикацији
Библиотеке Матице српске, Нови Сад

633(048.3)

CROPINNO Final Conference "New Approaches in Crop Improvement for Increased Climate Resilience" (2025 ; Novi Sad)

Book of abstracts [Elektronski izvor] / CROPINNO Final Conference "New Approaches in Crop Improvement for Increased Climate Resilience", 26 June 2025, Novi Sad, Serbia. - Novi Sad : The Institute of Field and Vegetable Crops, 2025

Način pristupa (URL): https://fiver.ifvcns.rs/handle/123456789/5445. - Opis zasnovan na stanju na dan 11.7.2025.

ISBN 978-86-86221-02-5

a) Усеви -- Климатски ризици -- Апстракти

COBISS.SR-ID 172160521
