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ecobreed
IMPROVING CROPS

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ECOBREED Organic Breeding Conference

Book of Abstracts

17 – 19 January 2024

Ljubljana, Slovenia

April 2024

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IMPROVING CROPS

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ECOBREED Organic Breeding Conference

17 – 19 January 2024

Glass Hall, Grand Hotel Union Eurostars,
Miklošičeva cesta 1, 1000 Ljubljana, Slovenia

Programme

Wednesday, 17 January 2024	
8:30	Registration
9:00	**Welcome & opening of the conference** • **Vladimir Meglič**, Agricultural Institute of Slovenia • **Andrej Simončič**, Agricultural Institute of Slovenia • **European Commission** (speaker TBA) • **Joži J. Cvelbar,** Agriculture Directorate, Ministry of Agriculture, Forestry and Food of Republic of Slovenia
9:45	**Session 1: The Organic Landscape and Policy Changes** Chair: Vladimir Meglič, Agricultural Institute of Slovenia Invited lectures: • **Freya Schäfer**, FiBl Germany e.V.: *Fostering Organic Seed Production and Use* • **Werner Vogt-Kaute**, Naturland e.V.: *ECOBREED Contribution to the EU Organic Policy*
10:45	Coffee break & networking in the Garden Hall
11:15	**Session 1: The Organic Landscape and Policy Changes** ***Round Table on Organic Breeding, Varieties, (O)HM and Seed Availability*** Moderator: **Paul Bilsborrow**, University of Newcastle • **Micaela Colley**, Organic Seed Alliance, USA • **Freya Schäfer**, FiBL, Germany e.V. • **Hubert Kempf**, SECOBRA Saatzucht GmbH • **Anna Pearce**, LC Smales & Son Ltd • **Samanta Dömötörová**, Ministry of Agriculture and Rural Development, SK • **Monika Messmer**, FiBL Switzerland • **Maja Žibert,** Agriculture Directorate, Ministry of Agriculture, Forestry and Food of Republic of Slovenia
13:00	Lunch & networking in the Garden Hall

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14:00 **Session 2: Plant Breeding and Genetics for the Improvement of Organic Varieties**

Chair: Heinrich Grausgruber, University of Natural Resources and Life Sciences

Invited lectures:

- **Hubert Kempf**, SECOBRA Saatzucht GmbH:
  Breeding Wheat Cultivars for Organic Agriculture – the Way of Secobra Saatzucht
- **Michael Schneider**, FiBL Switzerland:
  Precise OHM Tracing by Genomics

15:00 **Session 2: Plant Breeding and Genetics for the Improvement of Organic Varieties**

Chair: Heinrich Grausgruber, University of Natural Resources and Life Sciences

- **Heinrich Grausgruber**, University of Natural Resources and Life Sciences
  Marker-Assisted Selection in Wheat for the Improvement of Organic Varieties
- **Mario A. Pagnotta**, University of Tuscia:
  Organic Seeds Breeding in Durum Wheat for Mediterranean Environment
- **Dagmar Janovská**, Crop Research Institute:
  From the Gene Bank to the Field: Utilizing the Diversity of the Gene Bank in Buckwheat Breeding
- **Pavel Horčička**, Selgen, a.s.:
  Wheat Yield and Quality under Conventional and Organic Farming
- **Discussion**

17:00 **Poster session**

with food & networking in the Garden Hall

Thursday, 18 January 2024

9:00 **Sub-session 2a: Genomic Tools for Organic Breeding**

Chair: Vladimir Meglič, Agricultural Institute of Slovenia

Invited lecture:

- **Meiliang Zhou**, Chinese Academy of Agricultural Sciences:
  Research and Utilization of Buckwheat Germplasm Resources

9:30 **Sub-session 2a: Genomic Tools for Organic Breeding**

Chair: Vladimir Meglič, Agricultural Institute of Slovenia

- **Barbara Pipan**, Agricultural Institute of Slovenia:
  Buckwheat Germplasm: In-Depth Characterisation of Agro-Morphological and Genetic Diversity
- **Vuk Djordjević**, Institute of Field and Vegetable Crops:
  Marker-Assisted Selection for Soybean Organic Breeding
- **Matilda Ciucă**, National Agricultural Research and Development Fundulea:
  Screening European Winter Wheat Germplasm for Rusts Resistance Alleles using Molecular Markers

10:30 **Sub-session 2b: Conventional and Advanced Phenotyping**

Chair: Peter Dolničar, Agricultural Institute of Slovenia

- **Uroš Žibrat**, Agricultural Institute of Slovenia:
  Phenotyping of Winter Wheat Genotypes - Taking (some) of the Shine off

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- **Ankush Prashar**, University of Newcastle:
  Exploring High Throughput Tools for Decision Making in Potato
- **Pedrag Randjelović**, Institute of Field and Vegetable Crops:
  Soybean and High-throughput Phenotyping: Perceiving Growing Patterns in Different Environments
- **Aleš Kolmanič**, Agricultural Institute of Slovenia:
  Assessing the Competitive Ability of Winter Wheat (Triticum aestivum L.*) Varieties against Weeds*

12:00 Lunch & networking in the Garden Hall

13:00 **Sub-session 2c: Organic Breeding – Methodologies and Strategies (PPB)**

Chair: Dagmar Janovská, Crop Research Institute

Invited lecture:

- **Micaela Colley**, Organic Seed Alliance, USA:
  Exploring the Emergence of Participatory Plant Breeding in Countries of the Global North

13:30 **Sub-session 2c: Organic Breeding – Methodologies and Strategies (PPB)**

Chair: Dagmar Janovská, Crop Research Institute

- **Peter Dolničar**, Agricultural Institute of Slovenia:
  Participatory Plant Breeding Strategies in Organic Potato Breeding Program at Agricultural Institute of Slovenia
- **Vuk Djordjević**, Institute of Field and Vegetable Crops:
  Organic Soybean: ECOBREED Partner Contribution
- **Gyula Vida**, ATK Centre for Agricultural Research:
  Genetic Variability of Gluten Strength and Yellow Pigment Content in a Set of Winter and Facultative Durum Wheat under Low-Input Conditions

14:30 **Sub-session 2d: Young Researchers**

Chair: Mario A. Pagnotta, University of Tuscia

- **Luca Bonfiglioli**, University of Tuscia:
  Durum Wheat Characterization for Organic Agriculture and for Tolerance to Drought and Salinity
- **Marjana Vasiljević**, Institute of Field and Vegetable Crops:
  Fostering Farmer Engagement: ECOBREED Participatory Trials on Organic Soybean in Serbia
- **Janez Lapajne**, Agricultural Institute of Slovenia:
  Enhancing Potato Crop Analysis with Machine Learning and Multispectral Imaging in Field Conditions: A Study on Explainable AI Techniques

- **Ana Vojnović**, Agricultural Institute of Slovenia:
  Spectral Responses of Slovenian Potato Varieties under Water-Restriction Stress
- **Marion Champailler**, Agricultural Institute of Slovenia:
  Farmer Participatory Trials: Case study in Slovenia

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Friday, 19 January 2024

9:00 — Session 3: Variety Evaluation and Farmer Participatory Trials

Chair: Paul Bilsborrow, University of Newcastle

Invited lectures:

- **Salvatore Ceccarelli**, independent consultant:
  Variety Evaluation and Farmer Participatory Trials
- **Klemens Mechtler**, AGES - Austrian Agency for Health and Food Safety:
  Testing Agricultural Varieties for Organic Farming in Austrian VCU-System

10:00 — Sub-session 3a: Variety Evaluation

Chair: Paul Bilsborrow, University of Newcastle

- **Péter Mikó**, ATK Centre for Agricultural Research:
  Comparison of Agronomic and Quality Parameters of a Durum Wheat Diversity Panel Grown in Hungarian Organic, Low Input and Conventional Fields
- **Soňa Gavurníková**, National Agricultural and Food Centre:
  Qualitative analysis of European winter wheat tested within the ECOBREED project
- **Primož Titan**, RGA d.o.o.:
  Perennial Wheat in Reality

11:00 Coffee break & networking in the Garden Hall

11:30 — Sub-session 3b: Farmer Participatory Trials

Chair: Werner Vogt-Kaute, Naturland e.V. & Paul Bilsborrow, University of Newcastle

- **Werner Vogt-Kaute**, Naturland e.V.:
  Environmental Stability of Wheat Populations in ECOBREED Farmers Participatory Trials
- **Werner Vogt-Kaute**, Naturland e.V.:
  Protein-Yield – an Interesting Metrics for Organic Varieties
- **Paul Bilsborrow**, University of Newcastle:
  The Performance of Varieties, Populations and Mixtures of Winter Wheat from UK Farmer Participatory Trials
- **Anna Pearce**, LC Smales & Son Ltd:
  The Potential of Seed Dressings & Biostimulants for Organic Production
- **Adam Brezáni**, PRO-BIO obchodní společnost s r.o.:
  Buckwheat, a Special Chance for Eastern Europe?

13:00 — Closing of the conference

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Introduction

The project ECOBREED (*Increasing the efficiency and competitiveness of organic crop breeding*) is funded by the European Union Horizon 2020 funding scheme and brings together 24 partners from 14 different countries. The project ran for 5 years and had €6.2 million of funding available for activities.

ECOBREED aims to increase the availability of seeds and varieties for the organic and low-input sectors, to identify traits and combinations of traits suited to organic and low-input production environment including high nutrient use efficiency and weed competitiveness and to increase breeding activities for organic and low-input crop production.

The project developed methods, strategies and infrastructure for organic production, varieties with improved stress tolerance, higher efficiency and quality, and improved methods for producing high quality organic seed. One of the most visible results of the project is the registration of new plant varieties available under our registered trademark "ecobreed IMPROVING CROPS". Among the results, we can also highlight the improvement of pest control methods in organic production of potatoes, soybeans, wheat and buckwheat.

The ECOBREED Organic Breeding Conference took place from 17 to 19 January 2024 in Ljubljana, Slovenia. The three-day conference attracted more than 90 participants from 14 European countries as well as participants from China and the USA.

At the final conference, we presented a summary of the results of the ECOBREED project and invited high-level experts in the field to contribute to the conference: Salvatore Ceccarelli, an independent organic farming consultant, Micaela R. Colley from the Organic Seed Alliance, Klemens Mechtler from the Austrian Agency for Health and Food Safety (AGES), Freya Schäfer from the German Research Institute for Organic Agriculture (FiBL), Michael Schneider from the Swiss Research Institute for Organic Agriculture (FiBL) and many others.

There was also a very insightful Round Table on Organic Breeding, Varieties, (O)HM and Seed Availability with organic breeding and organic seed production experts (see livestream here).

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The performance of varieties, populations and mixtures of winter wheat from UK Farmer Participatory Trials

Paul Bilsborrow[1], Anna Pearce[2]

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In total 14 trials were carried out on winter wheat across 5 sites in the UK from 2020-23. The aim was to evaluate some of the best organic wheat varieties available in Europe (mostly bread-making quality), compare these with a farmer's own variety(ies), evaluate the potential of CCPs (Organic Heterogenous Material) and varietal mixtures. Trials were non-replicated, drilled with commercial farm machinery and managed by the farmers. Disease levels (leaf blotch and yellow rust) were recorded from flag leaf emergence until flowering at roughly 14-day intervals. Grain quality analyses (protein content, HFN and specific weight) were carried out after harvest. In terms of yield UK conventional varieties (KWS Extaste, Revelation KWS Dawsum outperformed European organic varieties of which the best in terms of yield, disease levels and grain quality was Wendelin. The variety Wendelin had a consistently high protein content often >13% and generally 1-2% higher that the popular UK Group 2 milling wheat KWS Extase. Wakelyn's YQ population was mid table in performance in most trials with the exception of 2023 where severe lodging of this variety occurred prior to harvest. The varietal mixtures evaluated showed no benefit in terms of grain yield or disease resistance.

Acknowledgements: This work received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 771367 (ECOBREED).

Durum wheat characterization for organic agriculture and for tolerance to drought and salinity

Luca Bonfiglioli*, Mario A. Pagnotta, Ieva Urbanavičiūtė

Tuscia University, Department of Agricultural and Forest Sciences, Viterbo, Italy

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Durum wheat is one of the main crops in the Mediterranean Basin and its production is already facing major challenges from climate change and the associated conditions, such as drought, heat, and salinity, with negative impacts on its productivity and quality of the product. Moreover, new varieties, suitable for low input agriculture, are needed to contrast the pollution from agrochemicals, and to reduce the production and profit discrepancy between conventional and organic farming. With the aim to improve the availability of seeds and varieties suitable for organic farming with high standards and tolerance to drought and salinity, a four-years field trial was performed screening durum wheat genotypes with different origin for traits of interest for organic farming. Simultaneously, was performed an experiment under controlled conditions applying drought and salt stress to some genotypes present also in the field. Phenotypic and genotypic differences were detected among the genotypes screened. Analysis on yield, grain quality, and stability, revealed new material suitable for organic farming and for new breeding programs. Under controlled conditions were found different strategies of stress-escape in genotypes that can be a great resource for drought and salt tolerance breeding programs.

Acknowledgements: This work received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 771367 (ECOBREED).

Buckwheat, a special chance for the Eastern Europe?

Adam Brezáni
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Buckwheat doesn't have any major pests or diseases, has a relatively short vegetation, it is a gluten-free crop making it perfectly suited for organic crop rotations. However, farmers have considered buckwheat as a semi-wild crop and there is limited information about varieties and their commercial availability compared to other crops. Organic buckwheat is annually grown at about 1 000 ha in Czech Republic, making it very niche crop with unstable market prices.

The differences between varieties are significant, which can result in unfulfilled expectations. Farmer participatory trials were set up in Czech Republic in 2021 and 2022 under a project ECOBREED. Altogether 20 different commercial varieties were tested and 4 populations from Slovenia. Selection of perspective varieties for grain and cover crop production was done. Practical recommendations for farmers were created. Demonstrational events have been proven as an effective method to exploit the results and findings to farmers.

Acknowledgements: This work received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 771367 (ECOBREED).

Variety Evaluation and Farmer Participatory Trials

Salvatore Ceccarelli
Independent Consultant
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Variety evaluation conducted as multi-environment trials (MET) are conducted as a routine part of any breeding program to identify superior cultivars for the region or the regions that are the target of the breeding program. In a conventional breeding program these are sometimes the only trials that are conducted in farmers' fields rather than on a research station. The reluctance to conduct trials in farmers' fields is often justified by the fact the trials in farmers' fields are not sufficiently precise. We argue that although they are very precise, they can also be very irrelevant. In participatory plant breeding, all the work is conducted in farmers' fields and therefore they are very relevant. The paper will describe several experimental designs and statistical analysis that can substantially increase their precision and allow the testing of many lines. A model of decentralized-participatory breeding program will be presented with a suite of different methods used in different stages.

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Marker-assisted selection for soybean organic breeding

Marina Ćeran[1]*, Johann Vollmann[2], Matilda Ciuca[3], Ion Toncea[3], Martin Pachner[2], Vuk Djordjević[1]

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Marker-assisted selection (MAS) is a valuable tool in crop breeding, including organic breeding. The application of molecular markers allows rapid screening at early developmental stages as well as more accurate and efficient identification and selection of plants with desired traits. Besides accelerating breeding, this approach reduces the need for extensive field trials and multiple generations of selection. Considering that organic breeding emphasizes sustainable practices and minimal environmental impact, MAS can reduce the need for excessive land, water, and resources typically required for conventional breeding. In addition, it can help breeders to develop organic-compliant varieties by targeting specific traits and preserving organic standards, providing more efficient and sustainable strategies for organic production systems.

Molecular markers were used to screen ECOBREED soybean germplasm harbouring traits relevant to organic farming, such as cadmium accumulation, supernodulation and disease tolerance to *Sclerotinia sclerotiorum* and *Diaporthe* complex. Genotypes with low cadmium accumulation should be used in organic food production to improve food safety, while supernodulation in soybean could be an important trait showing potential for increased nitrogen fixation. Molecular screening of genotypes for disease resistance is especially important in organic farming where chemical interventions are limited, offering an efficient and sustainable strategy for organic production.

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Farmer Participatory Trials: Case study in Slovenia

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As part of the ECOBREED project (Grant Agreement No. 771367), a range of varieties for 4 crops (potato, soybean, buckwheat and soybean) were tested in Farmer Participatory Trials (FPT). They were selected by researchers, farmers and experts and tested to see if they could cope with the technical and economic constraints of organic farming. Organic varieties should show rapid germination and development, competitiveness against weeds, resistance to diseases and pests, satisfactory yields with low organic nitrogen inputs, etc. We carried out trials in cooperation with farmers on 6 organic farms and in the field of the Agricultural Institute of Slovenia (KIS). A selection of 14 potato varieties, 8 soybean varieties, 8 buckwheat varieties and 22 winter wheat varieties were sown in 2 or 3 seasons. Data were collected by farmers and KIS. Chemical analyses were carried out by KIS. The FPTs were used to compare the results of the varieties in different environments and farming practices. The descriptive results of the FPT per variety were discussed. Statistical analyses were performed to compare the effects of the parameters on the dependent variables. For example, variety and location had a significant effect on potato yield. Stakeholders received the results through annual bulletins and demonstration days on the farms and at the KIS.

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Romanian Wheat Resistance Sources to Common Bunt Disease

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Common bunt produced by *Tilletia tritici* and *Tilletia laevis*, is a major disease for the wheat grown in organic system. In this study 14 winter wheat lines (obtained by crosses with different known sources of Bt genes and unknown resistance sources) were tested under artificial inoculation in Romania and Denmark (tested 8 different races on common bunt). Also, 27 synthetic amphiploids (SHWs) and 78 DH lines (obtained from Izvor x F00628G34-1 cross) were tested under artificial inoculation only in Romania. The results showed that in both fields from Denmark and Romania only four lines were free of teliospores: FDL94895GM1-21 (Bt12), FDL95601GM37 (Bt13), F00628G34-1 (1RS:1AL translocation) and F96915G1-1 (WGRC23). The resistance source, in WGRC23, probably comes from *Triticum monococcum* accessions PI 266844 or/and PI 355520. These sources have kept the resistance over time and across fungal races covering a broad range virulences occurring in Europe.

In this study were also observed six SHWs with 0% infected spikes: E10A, E15A, E22A, E30A, E32A and E34A. The molecular marker assay with TSM592 marker showed that 50 DH lines from 78 carry 1RS:1AL translocation and phenotypic observations showed that 32 lines from these were free of teliospores and the maximum of infection level was 8% while the DH lines without rye translocation showed the minimum infection level at 5% and the maximum at 100%. This result showed that rye translocation contributes to resistance to common bunt.

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Screening European winter wheat germplasm for rusts resistance alleles using molecular markers

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Rust diseases of wheat (leaf, stripe and stem rust), with a continued evolution of pathogens, constitute a major threat to wheat production worldwide and at the same time are a challenge for the breeders. Durable rusts resistance is a breeders' desire and a significant component for food security. This work reports the screening of 84 cultivars for rusts resistance alleles using DNA markers. In this study the cultivars were analyzed for the presence of resistant haplotypes of Lr34/Yr18//Sr57/Ltn1, Lr46/Yr29//Sr58/Ltn2, Lr26/Yr9/Sr31/Pm8, Yr5 and Yr15 using DNA markers. The results showed that 17 cultivars (20%) carry Lr34 resistance allele, 15 cultivars have Lr46 (18%) and of these, three cultivars (Mv Uncia, Semnal and Unitar) carry both resistant haplotypes (Lr34+Lr46). The Lr26 (1RS-rye chromatin) complex was observed in 10 cultivars (six with 1BL.1RS and four with 1AL.1RS). Two cultivars cumulated the rye chromatin and rust genes, Savinja (Lr34+1BL.1RS) and Unitar (Lr34+Lr46 +1AL.1RS). Molecular marker assay for Yr5 showed alternate Yr5 allele carriers, like YrSP allele (detected in 62 genotypes). In the case of Yr15 gene, the resistance allele was detected in five cultivars: Mv Karizma (Yr15+Lr46), Mv Suba, Mv-Elite-CCP (Yr15+1BL.1RS), IS Escoria and IS Mandala (Yr15+Lr46).

This study proves the value of marker assisted selection (MAS) strategy, for the parent's choice and acceleration of wheat rusts resistance cultivars development.

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Exploring the emergence of participatory plant breeding in countries of the Global North

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Participatory plant breeding (PPB) is increasingly employed in countries of the Global North despite significant investments in seed industry and advancement of genetic technologies. A recent state-of-the-art review inventoried PPB projects, to explore the applications of PPB in the US, Canada and Europe to inform future PPB efforts. This session presents select results of that review and highlights case studies demonstrating a wide range of models and methods employed across diverse crop species and reproductive biologies. An exploration of motivations of projects revealed improved adaptation to organic farming systems, conservation of crop genetic diversity, farmers' seed sovereignty, and avoidance of certain breeding techniques for philosophical reasons as common themes. Obstacles to PPB also emerged including challenges in sustained funding as well as addressing regulatory barriers to the commercial distribution of PPB varieties.

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Organic soybean: ECOBREED partner contribution

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One of the goals of the ECOBREED work package SOYBEAN was to develop soybean genotypes with improved agronomic performance and to offer know-how for cultivation practices tailor-made for low input and organic systems. During the project lifetime, the focus of activities was on phenotyping for biotic (weed, pest, diseases) and abiotic (drought and chilling stress) stress tolerance screening, as well as crop and nutritive quality and N fixation efficiency. A marker-assisted selection programme was established to identify genes/QTL of particular importance for organic soybean varieties. In addition, an assessment of the effects of cover crops and inoculation in the process of soybean seed multiplication was performed. Creating and selecting new soybean lines suitable for organic production was a key priority. After the first half of the project and the conduction of different trials and identification of useful traits, cross composite populations (CCPs) and soybean lines were available for further field testing. Chosen soybean lines went through the registration trials (2021-2022) to evaluate their performance and adaptability. The first ECOBREED soybean variety was registered by IFVCNS. NS ECOB is the variety with high protein content (00 maturity group) specifically selected for organic and low input production requirements.

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Participatory plant breeding strategies in organic potato breeding program at Agricultural Institute of Slovenia

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Within the ECOBREED project, existing potato breeding programme for resistance to different pests and diseases at Agricultural Institute of Slovenia (KIS) was upgraded with the selection of genetic material on KIS organic fields from the year 2021. The intention was to develop independent organic potato breeding program at KIS with primary focus on Potato virus Y and Late blight resistance R genes using molecular markers in marker assisted selection and selection of agronomy traits in organic production systems. To enhance the selection efficiency of the programme and test advanced clones in diverse environments and soil types, organic farmers were invited to join the programme as a part of newly developed participatory plant breeding scheme. The intention of the scheme is crop breeding with farmers in the driver's seat, where farmers participate in different steps of development of resilient organic potato varieties. Within the project, four organic Slovenian farmers joined the KIS participatory plant breeding programme in years 2022 and 2023 with the testing of advanced potato genotypes on their fields. In article different future participatory plant breeding strategies in KIS organic breeding program will be presented.

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The application of MAS for selecting potato genotypes with complex resistance in Hungary

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One of the biggest challenges for organic potato farming is the spreading of pests and diseases. The best solution for organic farming is to breed potato varieties that are resistant to some of the most important pathogens such as late blight (*Phytophthora infestans*) and viruses like PVX and PVY. Marker-assisted selection (MAS) enables the selection of potato individuals with the desired resistance gene composition without the need for extensive phenotypic testing.

In the breeding programme at Keszthely, germplasms of different wild potato species (*Solanum stoloniferum*, *S. andigena*, *S. demissum*, *S. chacoense*, *S. hougasii*) have been used in the past to incorporate resistance genes against virus, nematode and late blight infection into breeding lines and varieties. In the ECOBREED project, resistant potato varieties were combined with high-performing commercial varieties to maintain a high level of resistance and improve the agronomic properties of the progeny. The progeny was genotyped with molecular markers for known PVX, PVY and late blight resistance genes to select promising candidates for further breeding. During the project, the application of MAS resulted in 11 clones with complex resistance and favourable phenotypic and qualitative characteristics.

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Qualitative analysis of European winter wheat tested within the ECOBREED project

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The presented study tested 140 varieties of winter wheat, of which 6 varieties were selected (Aurelius, IS Laudis, Alessio, Ehogold, Capo, PS Dobromila) and grown on three organic farms and on organic experimental field in Slovakia, Hungary, Slovenia and Romania in the years 2020-2023. Quality analyses were carried out on harvest samples: bulk density, protein content, wet gluten content falling number and Zeleny sedimentation index. The presented results indicate that there were no statistically significant differences between the varieties in quality parameters. Nevertheless, Alessio variety achieved the highest values of protein content (11,4 %) and variety PS Dobromila achieved the highest wet gluten content (23,5 %) and sedimentation index (39 ml). The statistically significantly lowest bulk density (79,0 kg/hl) and falling number (259,5 s) was achieved in Slovenia. On the contrary, in Slovenia was achieved in average the statistically significantly highest protein and wet gluten content. Differences in sedimentation index values were not statistically significant between countries. The year 2020 was characterized by the statistically significantly lowest values of bulk density and falling number, on the contrary, the highest wet gluten content. In 2020, at the growing site in Slovenia, all varieties had a very low falling number, the reason was in very wet weather during harvest.

In conclusion we can say that all these selected varieties could be used effectively in organic farming systems. The quality of the selected varieties was at the same level, we did not detect statistically significant differences between the varieties. However, the quality can be significantly affected by the growing conditions given by the location and the external conditions of the environment, such as the weather.

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Quality of wheat varieties grown on organic farms in Slovakia

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As part of the ECOBREED experiment, we are dedicated to monitoring and selecting wheat varieties (*Triticum aestivum* L.) promising for further breeding and use in an organic farming system. The selected 8 varieties were grown on organic farms in Slovakia during 2020-2023. The varieties Aurelius, Capo, IS Laudis, Viki, Ehogold, PS Dobromila, Alessio, Arnold were selected. Varieties were analysed for grain yield, bulk density, protein content, wet gluten content, falling number and Zeleny sedimentation index. Capo, Ehogold, PS Dobromila varieties achieved the highest average bulk density of grain in the organic farming system (over 82 kg/hl), on the contrary, the lowest average volume weight was achieved by the Viki variety (78,1 kg/hl). Because the organic farming system is characterized by low inputs, this was also reflected in the results of quality parameters. Above all, low inputs were manifested by an average low proteins content and low wet gluten content in the evaluated wheat varieties. Of the eight selected varieties, which were also grown on organic farms, PS Dobromila variety achieved the highest quality during the years 2020-2023, especially for the highest wet gluten content.

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Marker-assisted selection in wheat for the improvement of organic varieties

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Nowadays, molecular markers play a key role in plant breeding programmes. Marker-assisted selection (MAS) and pyramiding of disease resistance genes are in line with the European Union's Farm to Fork Strategy and its targets to reduce the use of chemical pesticides and increase the acreage of organic farmland.

Within the ECOBREED project molecular markers applied to screen European winter wheat germplasm for the presence of quality, adaptation and rust resistance genes. Most widely exploited is the *Sr38/Lr37/Yr17* gene complex from *T. ventricosum* which is present in ≈42% of the studied genotypes. Resistance genes *Yr5*, *Yr10* and *Yr15*, which are assumed to work against the currently prevalent races of yellow rust, were rarely present and demonstrate the urgent need for their exploitation in organic wheat varieties.

MAS was also applied to transfer common bunt resistance QTL from North American resistance sources into European wheat germplasm. Multi-parent back-cross populations were developed and tested in the field for two years at two locations. The results revealed a clear association between the presence of resistance QTL and the incidence of bunted ears in the field and demonstrated the overall efficiency of MAS for this trait.

Finally, MAS was applied in the development of bulk populations in two different European winter wheats carrying and/or missing the functional *Gpc-B1* allele from wild emmer for high grain protein content (GPC). Multi-environment trials in six countries showed that the wild-type allele generally increased GPC, its absolute effect, however, is dependent on the genetic background. Further work is needed to transfer this valuable gene into the most advanced 'organic' breeding material.

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Plant genetic resources and their use in organic agriculture

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Organic agriculture and plant genetic resources are closely related topics, as organic farming relies on the conservation and use of diverse and adapted varieties of crops. Plant genetic resources are the raw materials that can help improve the productivity and quality of organic agriculture, as well as enhance its resilience to environmental stresses and pests. Organic agriculture also contributes to the in-situ conservation of plant genetic resources by maintaining and selecting local varieties that have a high degree of genetic variability.

An important goal of the ECOBREED project is to identify genetic and phenotypic variations for morphological, abiotic/biotic tolerances/resistance and nutritional quality traits that can be used in organic breeding. The first step to achieve this goal was to make the inventory of available genotypes of four crops: wheat, potato, soybean, and buckwheat. For this purpose, we have examined genetic resources of four crops stored in gene banks, used in previous European and national research projects, and available through plant breeding programmes and seed companies. We have also used agronomic data on available and used varieties in organic farming, varieties characterized by good disease resistance and quality. Selected 200 wheat genotypes originate from 12 different European countries, 197 potato accessions were identified from several databases, the list contains 242 soybean accessions that originated all around the world and of buckwheat were identified through international databases. Much of the material represents cultivars that were released in the last two decades and are included in either the European list or national lists.

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Conventional and advanced phenotyping of early and late winter wheat varieties

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Conventional and advanced phenotyping are two approaches to measure and analyse the physical and biochemical traits of plants. Advanced phenotyping uses high-throughput and automated techniques to capture data on plant morphology, physiology, and performance in different environments. Advanced phenotyping can also integrate genomic, transcriptomic, proteomic, and metabolomic data to link phenotypes with genotypes and molecular mechanisms. Conventional phenotyping of early (80 genotypes) and late (60 genotypes) varieties of winter wheat (*Triticum aestivum* L.) was carried out in organic plots in Borovce. The evaluation of winter wheat varieties was according to the wheat descriptor ECOBREED (D 2.1 Phenotypic DMS for wheat). Results from three years revealed a wide genetic variability. Conventional phenotyping was labour-intensive and time-consuming and provided valuable information on plant performance and quality but may not have captured the dynamic and complex responses of plants to environmental conditions. Therefore, conventional phenotyping was complemented by advanced phenotyping methods using high-throughput and automated techniques to collect data on plant morphology, physiology, and performance in the environment. 34 winter wheat genotypes from the ECOBREED nurseries were screened at advanced phenotyping for their growth and physiological performance. The set of morpho-physiological traits captured by RGB, chlorophyll fluorescence, thermal imaging and hyperspectral camera was dynamically analysed during this period in all the genotypes with 4 replicas per genotype and treatment. The tolerance of the genotypes to drought stress was characterized along all phenological stages from germination to ripening. Advanced phenotyping offers opportunities for improved breeding of crops that can adapt to changing climate and environmental conditions, as well as for understanding the complex interactions between plant genotype, phenotype, and envirotype. However, advanced phenotyping also poses challenges such as data acquisition, processing, analysis, and integration, as well as the need for standardized protocols and platforms.

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Wheat yield and quality under conventional and organic farming

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Organic farmers need varieties that are more plastic to specific regional environmental conditions, and able to achieve balanced yield and quality even under unbalanced soil conditions. The experiment was conducted for three years between 2021 and 2023 in four localities in Czechia. Two of the sites were under the organic (ORG) system, and two under the conventional (CON): Domanínek (ORG), Stupice (CON), Úhřetice (CON), and Uhříněves (ORG). Stupice, Úhřetice, and Uhříněves stations are characterized by a warm, slightly wet climate and highly fertile land suitable for wheat growing. Nineteen varieties of spring wheat (SW) and sixteen varieties of winter wheat (WW) were selected and sown on a small parcel of 10 m2 in two repetitions within a randomized complete block design. Quantity and quality parameters such as yield, plant height, protein content, volume weight, and thousand-grain weight (TGW) were measured, and the data was analyzed. In general, most parameters were lower in the organic system than in the conventional; the average yield was 35% (SW) and 29% (WW) lower than in the conventional system, protein content was 4% (SW) and 15% (WW) lower, plant height 4% lower for both SW and WW and TGW 4% (SW) and 3% (WW) lower. There was no difference in volume weight in SW, WW had a volumetric weight 1% lower in ORG than CON. The comparison between Stupice (CON) and Uhřínves (ORG) stations shows that organic farming in fertile regions has a potential and the gap between CON and ORG average yield could be lower than show national results - the wheat grain yield in the organic system in Czechia is 50% lower than in conventional.

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From the gene bank to the field: utilizing the diversity of the gene bank in buckwheat breeding

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In the contemporary context of climate change and the associated shift in weather patterns and the emergence of new diseases and pests, the challenges in agriculture, especially in organic production, are becoming increasingly clear. Organic agriculture, constrained by the prohibition of certain synthetic protective measures, relies primarily on natural plant defences to maintain production hygiene, quality and consumer satisfaction. To enhance the robustness of organic crop production, it is essential to breed crop varieties that are customized to their intended use and the specific environmental conditions of their cultivation. A crucial aspect of this breeding process is the availability of a diverse genetic material from which the parental components for crosses can be selected. Gene banks, which conserve a variety of accessions with different traits and potential uses, are invaluable in this respect. In the case of buckwheat in particular, gene banks serve as repositories for different accessions potentially used in breeding programmes. Central to this discourse is the comprehensive phenotypic characterization of buckwheat accessions in gene banks, which is essential for the description of unique genetic traits for the development of enhanced varieties. This study addresses phenotypic variability in gene bank collections and its application in meeting contemporary breeding objectives, such as increasing yield potential, enhancing resistance to biotic and abiotic stresses, improving nutrient profile and adaptability to a wide range of climatic conditions. The methods used in phenotyping and their integration into breeding strategies are described in detail. It also addresses the logistical and methodological challenges associated with translating genetic resources into practical breeding outcomes. It highlights the collaboration between gene banks, academic research institutions and agricultural practitioners and emphasizes the crucial role of multidisciplinary partnerships for progress in crop breeding. In conclusion, this presentation emphasizes the transformative potential of gene bank-derived genetic diversity in the breeding of buckwheat. It advocates for the sustainable conservation and judicious use of these genetic resources and emphasizes their indispensable role in developing innovative breeding solutions to meet the dynamic demands of global agriculture and food security.

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Variability of a Pannonian wheat collection used for organic breeding

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Wheat is the most important plant used for human consumption in Europe and represents the crop most widely grown in the organic agriculture. Moreover, wheat also represents the largest range of organic products available on the market. Because of its importance, for the improvement of organic wheat production great efforts and resources are invested. The main goal is to obtain high and stable yields. During the breeding process of wheat (*Triticum aestivum* L.), when creating a new variety for organic use, it is necessary to incorporate genes responsible for high yield potential and adaptability to different production conditions. In order to determine the variability of grain yield, hectolitre weight, 1000 grain weight and plant height, collection of 30 winter wheat cultivars widely grown in the Pannonian Plain was chosen. The experiment was carried out in a typical Pannonian location at the experimental field of the Institute of Field and Vegetable Crops, Novi Sad, Serbia. The results showed significant variations in the examined traits between the chosen cultivars. Knowledge about the variability between the wheat cultivars could be used for selecting the most suitable ones for breeding in the organic agriculture of the Pannonian Plain.

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Breeding wheat cultivars for organic agriculture – the way of Secobra Saatzucht

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Secobra Saatzucht (before 2007 Saatzucht Schweiger) is now developing wheat cultivars for organic agriculture for more than 25 years. The first variety listed out of our "mixed or hybrid" breeding scheme was the variety Naturastar, released in 2002 after having passed an extraordinary organic NL-trial of three years. Some years later official organic NL-trials have been established. As a private breeder we need to generate royalties. In 2023 the market share of organic wheat varieties in Germany was roundabout 8%. That means a breeder could only survive if he would have 100% market share. Due to his we developed a "special/hybrid" breeding scheme to develop varieties for organic agriculture in an effective and relatively cheap way.

Special crosses for organic agriculture are done at the beginning of the breeding regarding the special breeding goals of organic agriculture. These crosses would not have been made in our conventional program. From F2 to F5 this material is handled like the conventional one, that means single ear descendants without any treatment and little nutrient supply. The aim is to breed for height and resistance in these first years. From F5 onwards the "organic lines" are then tested in organic or very extensive conventional trials without any treatment and very little nutrient supply. In this years of the yield trials special attention is given to the specific breeding goals for organic agriculture like wheat competitiveness, height, yield under organic conditions and from our side the most important trait which is a good baking quality under low nutrient supply. After four years of testing one to three lines are then applied for organic NL trials here in Germany, hoping to get one line listed after three years of testing. The varieties bred for organic agriculture will not be tested and marketed conventional. Actually, we have some success with our varieties Wendelin and Rübezahl. Both were selected under our "special" breeding scheme for organic agriculture.

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Assessing the competitive ability of winter wheat (Triticum aestivum L.) varieties against weeds

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Assessing differences in weed competitiveness among wheat varieties and selection of competitive varieties for cultivation in systems without or with reduces use of herbicides, requires the identification of relevant characteristics and the development of appropriate methodologies for rapid and effective assessment. To achieve this objective, 3 distinct trials were conducted: a weed-free trial (employing herbicides for weed elimination), a trial using barley as weed competitors (with weed removal using herbicides), and a naturally weed-infested trial (without any weed management). These trials spanned 3 consecutive growing seasons (2020-2022) and involved 12 wheat varieties. The assessed traits included wheat/weed plant cove, biomass, height, and plant count; leaf count, leaf surface area and dry weight; grain yield and weed mimic yield; grain moisture; and thousand kernel weight. Observations were made during distinct growth stages, including booting, heading, anthesis, and ripening. The results highlighted correlations between the weed-suppressive abilities of winter wheat varieties and the evaluated traits. Utilising the weed mimic method facilitated the identification of wheat varieties demonstrating superior weed suppression and traits influencing weed competitiveness. The method employing weed competitors proved more reliable in evaluating wheat's weed competitive ability, displaying less variation compared to naturally weeded trials. The strongest negative correlations were observed between the number of weed competitor plants and wheat height and biomass. But the dry biomass of weed competitors showed a strong positive correlation with the number of competitor plants and a negative correlation with wheat biomass and height. Weak to moderate correlations were found between plant cover and wheat leaf count or Leaf Area Index and weed count/biomass across different wheat growth stages. Rather than being attributed to a single trait, competitive ability encompasses a combination of different traits. Based on the dry biomass of weed competitors, the tested varieties could be classified displaying good weed competitive ability (Primorka, Marinka, Bernstein, and Vulkan); moderate weed competitive ability (Izalco CS, Savinja, Illico, Alixan, Gorolka, Reska); and low weed competitive ability (CCB Ingenio, Tata Mata).

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The impact of different densities of selected invasive weeds on the grain yield of three soybean genotypes

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The aim of the experiment was to assess the competitive abilities of three soybean genotypes and selected invasive weeds based on soybean grain yield (t ha[1]).
Field trials with competition between three soybean varieties (NS Apolo, Fortuna, NS Zmaj) and three invasive weeds (*Abutilon theophrasti*, *Ambrosia artemisiifolia* and *Xanthium strumarium*) were conducted at Novi Sad (2020-2022). The split split plot design with four replications were used and plot size was 30 m2. Weeds were sown at the same time with densities of 0.5, 1, 5 and 10 weeds per m-1 of soybean row. The three central rows of the plot were used to calculate the soybean grain yield. *X. strumarium* caused the highest yield losses. Although 2020 was favorable for soybean growth, mean values of grain yield of soybean showed that in some treatments the Fortuna variety was showing higher grain yield compared to NS Apolo and NS Zmaj. Due to the deficit of precipitation in 2021, in the periods when it is necessary for the formation of grain yield and the contribution of other factors, genotypes NS Apolo and NS Zmaj showed higher grain yield than Fortuna. In 2022, which was extremely dry (without enough rainfall during the season), there were no significant differences between genotypes.

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Enhancing potato crop analysis with machine learning and multispectral imaging in field conditions: a study on explainable AI techniques

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Potato cultivation is vital for global food security, emphasizing the need for sustainable farming practices. The integration of advanced technologies, like unmanned aerial vehicles (UAVs) and multispectral imaging (MSI), has transformed agricultural research by enabling precise crop monitoring. This study employs a boosting machine learning algorithm and explainable AI techniques to transparently analyse relationships between spectral features and crop parameters, aiming to enhance decision-making in agriculture. Our primary goal was to unravel the complex dynamics of potato crops, fostering agricultural productivity while bridging the gap between technological innovation and sustainable practices. This research conducted in Slovenia during the summer of 2023 focused on eight distinct potato cultivars grown ecologically or conventionally. Using the MicaSense RedEdge-M multispectral camera on a UAV, three scanning sessions captured detailed images of the field's potato plants. Images underwent orthorectification, transformation into reflectance values, and georeferencing using a GPS device. In-depth insights were gained through explainable AI techniques, such as SHAP and UMAP, focusing on distinguishing various potato varieties. The F1 score exhibited a decreasing trend with additional varieties in both ecological and conventional setups. Highest scores were observed when differentiating between two varieties, while discrimination of eight varieties yielded lower scores. The Chlorophyll Vegetation Index (CVI) emerged as the most informative spectral feature, along with specific spectral channel ratios (blue and green, red and blue). Performance metrics indicated superior scores for conventionally grown potato varieties, emphasizing an R2 of 0.54 and 0.38 for SPAD and GSW, compared to 0.35 and 0.26 for ecologically grown potatoes. Our research underscores the importance of employing explainable AI methodologies in uncovering complex interrelationships among potato varieties and crop parameters.

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Pathogenicity of *Fusarium verticillioides* isolates on wheat spikes

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Fusarium verticillioides is major fungal phytopathogen of cereals. The main host is maize, but this species also poses a great concern to other cereals among which wheat stands out. *F. verticillioides* is toxigenic species that produces fumonisins as the major secondary metabolite along with trace levels of beauvericin, fusaric acid, fusarin C, gibberiliformin, and moniliformin. Being a potential contaminant in cereals and its processed food products it is posing a threat for human and animal health from a global perspective. The aim of this study was to examine the pathogenicity of *F. verticillioides* isolates on wheat spikes. Pathogenicity was examined on wheat spikes in trial studies in Zemun Polje. Spikes were inoculated with spore suspension of seven *F. verticillioides* isolates. The inoculation was performed when 50% of the spikes were in flowering stage after which the inoculated spikes were covered with PVC bags. After 48 hours the bags were removed. Based on the area of the spikes affected by fusariosis the infection rate was assessed. The scale from 1 to 7 was applied and the disease index was calculated based on these scores. The spikes were examined three weeks after inoculation. The average score of virulence of *F. verticillioides* isolates ranged from 2.95 (isolate 4290) to 3.70 (isolate 4500). The disease index was from 41.12% to 49.44%. Considering that *F. verticillioides* is a highly important wheat pathogen that causes economic damages the incidence of this species should be monitored.

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Phenotypic behavior of wheat cultivars tested under organic management in south-eastern Romania

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Eighty-three European winter wheat cultivars and breeding lines were tested from 2020 to 2022 under organic conditions at NARDI Fundulea. The three seasons were contrasting with respect to rainfall, i.e. 2019/20 and 2021/22 experienced drought, while 2020/21 had normal precipitation. Heading date, plant height (PH), spike number per m2 (SN), grain yield (GY), grain protein content (GPC), thousand kernel weight (TKW) and test weight (TW) were analyzed. Significant positive correlations were obtained between PH and SN, GPC and TW, and between TW and GPC; significant negative correlations between GY and PH, GPC and TW, and between TKW and SN. Some cultivars had significant differences from the trial mean for each of the analyzed traits. Molecular markers were applied to screen the germplasm for the presence of wheat-rye chromosome translocations, and allelic forms of genes for plant height, sensitivity to photoperiod, TKW and the number of spikelets per spike. Based on molecular markers results, were found many genetic profiles in the wheat cultivars better adapted for organic agriculture. Identifying cultivars with desired traits is an important step in breeding programs. Obtaining a variety more adapted to organic conditions can be achieved by making as many crosses as possible between genotypes with desired agronomic traits and selecting the progenies under organic conditions.

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Testing agricultural varieties for organic farming in Austrian VCU-system

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Brief review (since 2000) of the development of VCU tests for organic farming. Crop types included: bread wheat, barley, triticale, rye, potato, field pea, soybean. Expansion of the parameter list to include e.g. youth development, soil coverage, leaf attitude, susceptibility tests for the various species, adaptation of the test network and the guidelines for variety testing. Current situation and outlook considering the related EU directives.

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Comparison of agronomic and quality parameters of a durum wheat diversity panel grown in hungarian organic, low input and conventional fields

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Quality and agronomic performance of 30 durum wheat genotypes were examined in Hungary between 2019-2022 in three management systems (medium and low input conventional, organic). Analysis of variance revealed significant year, management, genotype and their interaction effect on heading, lodging, yield, grain physical parameters, test weight (TW), thousand kernel weight (TKW), gluten content, gluten index, but the year effect for yellow index was not significant. In the case of ground cover and gluten content, the management×genotype interactions were not significant, while ground cover and yellow index also couldn't show any significances in year×management×genotype interactions.

Based on the discriminant analysis, the management systems and the years were clearly separated within each other in the case of all the phenotypic parameters and yield components. At the same time, quality traits overlapped each other in the case of the management systems and the years.

Average yield of the experiment was between 5.79-6.02 t/ha. TW was between 78-81 kg/hL on average, TKW varied between 42-48 g considering the average of the three field trials. The wet gluten content, the gluten index, and the Minolta b* value varied within a wide range based on the average values of the 3 years and 3 management systems.

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Organic seeds breeding in durum wheat for Mediterranean environment

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According to the European Union Farm to Fork strategy, at least 25% of the EU agricultural land shall be under organic farming by 2030. However, the lack of wheat varieties specifically adapted and selected specifically for organic conditions and lower input of pesticides and fertilizers in organic production systems result in lower grain yields.

The aim of the present study, conducted in the frame of the ECOBREED project (European Union's Horizon 2020 research and innovation program under grant agreement No 771367), was to select suitable durum wheat accessions for organic farming in the Mediterranean region.

The trial started in 2018 at Tuscia University, Central Italy, with a preliminary evaluation of 72 durum wheat genotypes, including old varieties, landraces, and new accessions developed in the Central European and Mediterranean areas. The screening was focused mainly on traits important for organic farming, including crop ground cover/competitiveness with weeds, disease resistance/tolerance, but also grain yield, protein content, etc. After a first year of pre-screening, 27 genotypes were selected and evaluated in the field trial for three years more. The accessions were also characterized genotypically by SSR markers associated with traits of interest.

The study allows us to identify the most suitable accessions for organic agriculture with wide adaptation to different environmental conditions, and one of them was submitted to the Italian Ministry for Variety registration.

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The potential of seed dressings & biostimulants for organic production

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An insight into the trials of six organic biostimulant seed dressings & two biostimulant sprays on wheat crops at farmer participatory trial sites both in UK and in Austria. Looking at the impact that they have on both yield & grain quality.

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Plant breeding in organic agriculture and its impact on climate change

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Organic and low-input farmers usually sow seeds produced in conventional agriculture that traditionally include a large amount of mineral fertilizers and pesticides. They have a greater need for sustainability and high-yielding varieties that are adapted to the farming conditions of organic agriculture. The aim of this paper is to highlight the importance of developing organic varieties that positively influence climate change. For example, by breeding alfalfa, whose roots penetrate deep into the soil, researchers are creating varieties that are more resistant and more adapted to organic farming conditions. Alfalfa roots release their exudates which contribute to carbon sequestration, a measure to mitigate the effects of climate change. By breeding and creating varieties farmers will have greater choice of organic seeds, which leads to greater use of organic fertilizers that directly contribute to carbon sequestration. Use of pesticides that are prohibited in organic farming will be reduced or completely excluded. Organic agriculture is fast growing while organic breeding is not that widespread, and it takes a long period of time for new varieties to get on the market all over the world. It could be accelerated by the cooperation of a greater number of scientists from different companies or countries.

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Soybean response to different planting dates in organic farming system

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Selecting the correct combination of variety, maturity group and planting date could extend the productive period and increase soybean grain yield in organically managed cropping systems. Organic soybean producers tend to plant soybeans with a delay in typical sowing date (usually 7-10 days), to prolong time for weed management and enhance the control of early-season annual weeds. On the other hand, sowing after optimal date carries the risk of poor emergence due to drought, which often occurs in late spring in region of Serbia, as well as the risk of not providing adequate amount of time for growth and development, particularly in late-season soybean varieties. The aim of the research was to examine the potential of 4 locally developed soybean varieties from maturity groups (MG) 0 and I for organic production, and identify the most favourable combination of planting date, variety and MG for achieving satisfactory yield in organic conditions. During the year 2023, field trials were set up in organically managed site, at the experimental fields of Maize Research Institute Zemun Polje, Belgrade. Two sowing dates were applied (27 April and 3 May). The average grain yield of four soybean varieties sown in the second date was for 63% higher than yield of varieties sawn at the first term. Although varieties from MG 0 and MG I sown in the first period achieved a lower yield compared to the same varieties sown in the second period, it could be observed that the difference between the average yield of MG 0 and MG I varieties sown in the second date was only 3.21%. The best performing variety for organic conditions in terms of grain yield was variety Lela from MG 0 in the second sowing date. Sowing date delay led to yield increase in varieties of both MG, while the positive reaction was much more pronounced in the early varieties.

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CREDIT Vibes - Twinning Green-editing Vibes for FΘΘd

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CREDIT Vibes presents a cloud of Creativity, Research, Education, Development, Innovation, and Transformation (CREDIT) where the training of the highly skilled researchers and non-research staff is the priority. CREDIT Vibes are launched healthy food and feed, a healthy eco-friendly environment, and healthy life on a healthy planet. It was guided by the idea that if Maize Research Institute from Serbia is structurally transformed and thus improved transfer of agro-technology and agro-knowledge and increase number of manageable projects, other institutions in Serbia and the region will copy that pattern and enhance-self. When several smaller micro-transformations come together, the community's interest rises to the global level, and excellence is born. The main project's objectives are to transform and access excellence following the scientific and technology roadmaps and thus extend networking and collaboration in the region and Europe Research Area. CREDIT Vibes expects broader scientific, economic, and societal effects in raising the excellence of Maize Research Institute, which will open new science pathways and thus increase the number of manageable projects. Furthermore, increasing the transfer of agro-knowledge and agro-technologies into the economy by 15% will be the main long-term propeller of economic growth.

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Buckwheat germplasm: in-depth characterisation of agro-morphological and genetic diversity

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In-depth characterisation of the agro-morphological and genetic diversity of diverse germplasm is indispensable for identifying genomic regions controlling important agronomic traits and elite accessions holding favourable alleles that can be used for future marker-assisted breeding programs. In this study, we performed a detailed phenotypic and molecular characterisation of a diverse worldwide collection of the two closely related buckwheat species, *Fagopyrum esculentum* and *F. tataricum*, with contrasting mating systems using a large set of agro-morphological traits and SSR markers in order explore in details the genetic relationship between the two species and contribute to better understanding of the role of mating systems on the patterns of their genetic diversity and structure. The genetic diversity of *F. esculentum* was significantly higher than that of *F. tataricum*. However, for both species, this diversity was not significant between regions, indicating frequent seed exchange and/or recent extensive cultivation and selection. In addition, LD was very low between the SSR markers analysed, which is a desirable feature for using this germplasm panel for association studies and deciphering genetic control of agronomic traits of interest. The variation in agro-morphological traits analysed in our study was controlled by many genomic regions with pleiotropic and multi polygenic effects.

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Agro-morphological differences within common bean composite populations

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Common bean (*Phaseolus vulgaris*) has higher protein content than cereals and is used as a meat substitute, especially in economically less developed countries and by people who follow a vegetarian diet or want to reduce their meat consumption. P. vulgaris is cultivated worldwide and its adaptability to different environments and cultivation methods favors great genetic diversity within and between populations. In our study, 50 common bean composite populations were characterized under field conditions in 2022 using 86 established common bean descriptors. Composite populations were characterized by differences in primary or secondary seed coat color and included 2 to 5 different seed phenotypes. The aim of our study was to search for further agro-morphological differences within the composite populations. The results indicate that common bean composite populations differ within agro-morphological traits. Most of these differences concern the color of flower and physiologically mature pod (60%), pod suture string (52%), days to flowering and maturity (50%), pod curvature (48%), terminal leaflet size (42%), pod position in the plant (38%), hypocotyl pigmentation (34%), plant type (30%), pod cross-section (24%) and leaf persistence (22%). Further research aims to investigate the genetic variances to gain a deeper understanding of compensatory mechanisms within these populations.

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ECOBREED: Strategies for wireworm (Coleoptera: Elateridae) control based on entomopathogenic fungi of the genus Metarhizium in potato

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In the H2020 project ECOBREED (grant agreement no. 771367) we tested entomopathogenic fungi (EPF) *Metarhizium brunneum* and *Metarhizium robertsii* for wireworm control. The study included different modes of action of the fungi, including plant growth stimulation, bioaugmentation and the "attract and kill" approach. We tested six highly virulent *Metarhizium* isolates from the Agricultural Institute of Slovenia in three formulations: potato tubers soaked in EPF suspension, EPF formulated on rice, and a combination of both. Additionally, we compared these EPF treatments with a full (30 kg/ha) and a half (15 kg/ha) dose of Attracap (Biocare GmbH, a.i. *M. brunneum* Cb15-III), together with the insecticide Force 1,5 G (Syngenta, a.i. tefluthrin) and untreated tubers as controls. Two field trials were conducted in 2020 (A1 and A2) and two in 2021 (B1 and B2). The bioaugmentation method, especially the EPF formulated on rice, effectively reduced the proportion of damaged tubers. Thus, in A2, the combination of potato tubers soaked in EPF suspension and EPF formulated on rice resulted in a 21 % reduction in the proportion of damaged tubers, and in B1, all treatments proved effective in significantly reducing the proportion of damaged tubers, with EPF formulated on rice being the most effective at 44 %.

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Soybean and high-throughput phenotyping: perceiving growing patterns in different environments

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In the previous decade, new technologies based on remote sensing and photogrammetry were established as a powerful tool for non-destructive estimation of different plant traits. The high-throughput phenotyping (HTPP) implies the utilization of these tools and techniques, resulting in a fast and accurate assessment of crop development data. In soybean breeding, traditional phenotyping is recognized as a bottleneck in the current selection of superior lines mainly because of the inefficiency and resource consumption. The HTPP could be applied to overcome these shortcomings and not just for the prediction of plant characteristics from a single time point but also for perceiving crop growth based on multi-temporal data. This study aimed to analyze soybean growing patterns in different environments (drought and control) based on the estimated height and biomass of 206 genotypes (early and late varieties) sown in 2020 and 2021. In both seasons, each trait was predicted in eight-time points with previously developed HTPP models and protocols. The estimated values were used to create growing curves and evaluate analyzed genotypes based on their performance. Early varieties were dominant for both traits in drought conditions. In the control, the late material performed better regarding height while early genotypes accumulated more biomass.

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Virulence of *Fusarium proliferatum* isolates on durum wheat spikes

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Durum wheat is the second most important crop of wheat and the tenth most important crop in the world, which includes about 6% of the area under wheat cultivation and its annual production is between 37-40 million tons. The amount of protein, minerals, vitamins, and carotenoid pigments is higher than bread wheat which makes durum wheat an important source of energy. *Fusarium proliferatum* is plant pathogenic fungi that causes economically important disease often leading to substantial crop loss and yield reduction. The aim of this study was to examine the virulence of 16 *F. proliferatum* isolates on durum wheat spikes. The experiments were conducted in two year study (2017 and 2018) in Zemun Polje, Serbia. The spikes were inoculated with 20 ml spore suspension in early morning hours when 50% of the plants were in flowering stage. After inoculation, spikes were covered with PVC bags which were removed after 48 hours. After three weeks the spikes were evaluated according to a scale of one to seven based on the percentage of spike area with symptoms of fusariosis. During the first year of examination *F. proliferatum* isolates had average virulence scores from 1.15 to 2.75. During the second year of isolate virulence testing, the average virulence scores were higher for all isolates and ranged from 4 to 5.45. In the first year of research, two groups of *F. proliferatum* isolates were distinguished, which did not statistically significantly differ. During the second year of research, isolates 4454, which has the lowest average virulence score, and 4437, which has the highest average virulence score, were singled out. All other isolates are not statistically significantly different. The results of the virulence test on the durum wheat class indicated that there is a statistically significant difference between the two years of research. In the second year of the research, all isolates were more virulent, which is a consequence of the climatic conditions of that year. The increased amount of precipitation at the time of seeding favored the development of the infection, so the virulence scores were higher in the second year.

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Fostering organic seed production and use in the European Union

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According to the EU Organic Regulation No. 2018/848, Article 53, Paragraph 1, non-organic seeds, and planting material should no longer be used in organic farming from 2037 onwards. However, in the European Union, the availability of organic seeds and planting material, as well as the diversity of the propagated varieties for many crops, is currently not sufficient. Due to this supply gap, there is an ongoing need in organic plant production to use non-organic, untreated plant propagation material through derogations. Increasing transparency, accountability, and participation at national as well as at EU level can promote a level playing field and foster investments in the sector. In several EU member states, national organic seed expert groups advise the competent national authority to implement measures, provisions, and incentives, such as improving the functionality of national organic seed databases, analysing and publishing data on organic seed supply and non-organic seed use, implementing crop provisions to limit the number of derogations on non-organic seed, and maintaining testing networks to provide information on suitable varieties for organic farming. Furthermore, national seed expert groups could support their authority in drafting national roadmaps to phase out derogations on the use of non-organic reproductive material by 2037.

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Precise OHM tracing by genomics

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Cropping organic heterogeneous material instead of uniform varieties is an emerging market in the organic sector. For the official registration, but also the on-farm adaptations, uncertainties exist on how to differentiate populations. Besides, generations of the same bulk and how adaptations towards environments alter the composition of the populations are pressing issues that need to be addressed with precision.

We showcase how a genetic approach can identify allele frequency differences down to the gene level between environments and generations. Based on the allele frequency comparisons, we can assume the phenotypic composition of the population and how environments and climatic events have altered it over time. Further, crossing-over events can be identified to highlight the success of introgression. The presented method is highly cost-efficient and is based on pooled sample sequencing.

The method was validated in biparental populations of spring barley, winter rape seed, and winter wheat, which have undergone up to 20 years of local adaptation towards organic and conventional farming practices without artificial selection. Further research is in process to eliminate the need for knowledge about parental haplotypes.

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Phenotypic characteristics of *Fagopyrum esculentum* and *Fagopyrum tataricum* genetic resources grown in pot experiment

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Characterizing the phenotypic diversity of *Fagopyrum* spp. is crucial to adequately exploit the potential of germplasm collections and to identify important traits for future breeding programs and sustainable use. The phenotypic diversity of a global collection of the two cultivated buckwheat species *Fagopyrum esculentum* and *Fagopyrum tataricum* (187 and 52 accessions, respectively) was analysed using 35 phenotypic descriptors for plant, stem, inflorescence, flower, leaf and seed traits. The descriptors were adopted by ECOBREED, the International Union for the Protection of New Varieties of Plants (UPOV) and the International Board for Plant Genetic Resources (IBPGR) and applied to the buckwheat collection grown in a pot trial at the Agricultural Institute of Slovenia in Ljubljana in 2021. The descriptors were categorised into classes based on various predefined scales and intervals. In addition to the observations and assessments, extensive photographic material was taken for each genetic resource during the growth period. All quantitatively measured or qualitatively assessed traits showed a wide range of variation between the assessed *Fagopyrum* spp. accessions. Overall, the data obtained provided deep insights into the phenotypic diversity between the common and Tartary buckwheat accessions and point to future directions for genome-based breeding programs and germplasm management.

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Characteristics of the grains of different buckwheat varieties grown in field trials in two consecutive years

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Common buckwheat and Tartay buckwheat are the most widely cultivated and consumed *Fagopyrum* species worldwide, and the evaluation of grain characteristics of the different varieties plays an important role in their utilisation. In 2019 and 2020, a total of 11 buckwheat varieties (ten common, one Tartary) were grown in northeastern Slovenia under Central European growing conditions. The characterization of the grains included physical properties (TGW – thousand-grain weight, average seed width and length, length/width ratio), the determination of total phenolic compounds and a multi-element analysis. The TGW ranged from 12.3–29.4 g, the grain length from 4.1–6.8 mm and the grain width from 2.8–5.3 mm. Under the given growing conditions, the Billy variety developed the largest grains in both years and La Harpe and Doris the smallest grains. The total phenolic compounds varied from 4.4–15.3 mg GAE/g. The content of macro- (K, Mg, P, Ca, S) and microelements (Na, Cr, Mn, Fe, Co, Cu, Zn, Mo) varied considerably between the varieties. The highest coefficient of variation was observed for Fe, total phenolic compounds, Ca, Co and Cr (>30%). A very strong positive significant Pearson correlation (≥0.80) was observed for eight pairs of variables. The evaluation of buckwheat varieties revealed considerable diversity in grain traits studied.

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Perennial wheat in reality

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Early attempts to perform crosses between wheat and its perennial relatives date back to the 1920s and 1930s, when scientists in the former Union of Soviet Socialist Republics (USSR), the United States, Germany and Canada attempted to combine the genome of wheat (*Triticum* sp.) with perennial grasses like *Elytrigia repens* (L.) Desv. ex Nevski. Several foreign authors state that first known perennial wheat cross is a result of breeding work of the Russian botanist and plant breeder Nikolay Vasilevich, Cicin. The new plant species was named *Tritítrigia*, as a combination of two Latin names (*Triticum* – wheat, *Elytrigia* – sorghum). The cultivar Montana-2 is known as the first perennial wheat variety that appeared in agricultural practice. Within the ECOBREED project different types of perennial wheat wide crosses (e.g. (*Tr. aestivum* × *Th. intermedium*) × *Tr. aestivum*, (*Tr. aestivum* × *Th. intermedium*) × *Th. intermedium*, *Th. intermedium* × *Tr. aestivum*) were developed. Perennial accessions resulting from a cross between *Th. intermedium* × *Tr. aestivum* proved to be particularly interesting. In this kind of breeding work, problems arose, mainly with the phenomenon of male sterility. Therefore, additional crossings with accessions from the tribe *Triticeae* are planned, which will contribute to the restoration of fertility.

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An innovative approach in plant breeding to mitigate climate change in organic agriculture

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Developing cultivars for organic farming through plant breeding is a step toward improving product quality, disease, and insect resistance, but also to mitigate climate change. Organic production, which is aimed at protecting natural ecosystems by reducing the use of chemicals, presents challenges and opportunities for new approaches in plant breeding. The combination of indigenous varieties and wild relatives enables the creation of new varieties with improved stress resistance, adaptability, and quality, which is crucial for the breeding and development of cross-composite populations. The integration of the concept of cross-composite populations and speed breeding represents an innovative approach for the improvement of cultivars within the breeding program. It allows the development of new varieties that meet the specific requirements of organic farming more quickly. Cross-composite populations created with the primary goal of organic farming can increase above-ground and below-ground biomass, directly contributing to the secondary goal of carbon sequestration. Organic farming systems often integrate the concept of carbon farming by focusing on growing crops that increase carbon absorption from the atmosphere. Cross-composite populations and speed breeding in organic agriculture can be the most important step toward creating varieties adapted to climate change while also contributing to the carbon sequestration process.

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The use of crop wild relatives in forage legumes breeding program as a response to climate change

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The resulting climate changes and the increasingly frequent occurrence of extreme and/or variable climatic conditions during the growing season have a negative effect on the yield and quality of agricultural crops. One of the responses to mitigate the impact of climate change on agricultural production is creating widely adaptable cultivars that are genetically tolerant or resistant to a broad range of abiotic and biotic stresses. Successful development of new improved cultivars in the alfalfa and red clover breeding programs requires a novel approach during the selection process by introducing new gene pools into the core collection for complex adaptive traits. Crop wild relative of alfalfa and red clover represent a valuable plant resource because they are an important source of genetic diversity, contain alleles and adaptive traits that can be incorporated into elite cultivated germplasm. Therefore, one of the main activities in our perennial forage crops breeding program will be the collection of unadapted alfalfa and red clover germplasm of different origin. After the characterization and evaluation of the collected germplasm, the most promising materials will be identified as a source of desirable traits/genes for the expansion of the genetic base of the existing selection material and/or the future production of new resilient and stress-tolerant cultivars.

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Fostering farmer engagement: ECOBREED participatory trials on organic soybean in Serbia

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Farmer Participatory trials (FPTs) promote cooperation and knowledge exchange among farmers and researchers in specific agro-climatic conditions. Farmers who actively participate in field experiments are empowered to share their knowledge and preferences. To test and spread innovations in organic production, farmers actively participate in the decision-making process regarding plant variety selection. Farmer participatory trials for organic soybean production were established in five European countries as part of the ECOBREED project. The goal of these trials was to support farmers in selecting new varieties for their respective pedo-climatic zones and locations. This involves farmers directly in the process of developing new soybean varieties, particularly when it comes to working with breeders to observe cross composite populations (CCPs). FPTs for organic soybean were set up in Serbia (2021-2022). Up to 10 soybean varieties were tested on up to 5 locations for two years period. Trial results have big variations within specific locations and production years. Organic farmers continued with testing some subset of soybean varieties in 2023. FPTs are pathway for increasing the uptake of new and improved soybean varieties for low-input and organic production.

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Genetic variability of gluten strength and yellow pigment content in a set of winter and facultative durum wheat under low-input conditions

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Breeding durum wheat for organic conditions is currently not widespread, however, modern varieties often perform poorly under organic conditions. Under low-input conditions, the expected result of durum wheat genotypes in organic cultivation can be well estimated. Durum wheat semolina of excellent pasta-making quality is characterized by strong gluten structure and high yellow pigment content. The strength of the gluten matrix can be determined by measuring the gluten index, while the yellow pigment content by the Minolta b* value in the breeding programs. In our experiment, we examined winter and facultative durum wheat varieties. A set of 100 varieties and breeding lines were tested under low-input conditions from the durum wheat breeding programs of 12 countries. The genotypes represent approximately the results of the last 50 years of winter and facultative durum wheat breeding efforts. The two main factors (Year and Genotype) and their interaction also proved to be significant. In the second step, we investigated the genetic determination of the two traits. To determine the repeatability (h2), the variance components were calculated. Based on the high repeatability values, the genetic determination of both the gluten index and the Minolta b* value was extremely strong (Gluten index = 0.949; Minolta b* = 0.978). According to our results, the two quality characteristics can be efficiently improved even under organic conditions.

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Plant interference and invasive capacity: a battle for development

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Plant interference and invasive capacity are interconnected phenomena that impact ecosystem dynamics and biodiversity. Plant interference, including allelopathy and competition, shapes plant communities' structure and growth, while invasive capacity refers to certain plant species' ability to colonize and establish themselves in the environment, often owing traits that outcompete other species. In this research, 30 wheat genotypes were evaluated to know their potential to sustainably manage two herbicide-resistant weeds, the monocot *Lolium rigidum* Gaud. and the dicot *Portulaca oleracea* L. Shoot and root invasive capacity and seedling vigor index of both weeds were calculated when growing alone (control) or after co-culture with each wheat genotype (treatment). The results showed that wheat genotypes are more effective to sustainably manage *L. rigidum*, as the shoot/root invasive capacity of this weed was significantly reduced after growing with 24 out of 30 wheat genotypes, while this phenomenon was only observed for 18 out of the 30 wheat genotypes after the co-culture with *P. oleracea.* In this context, we propose 'Capo' as the most promising wheat genotype against the monocot weed, and 'Glosa' against the dicot weed. Even so, some of the genotypes showed strong ability for sustainably manage of both weeds, such as Spontan.

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ECOBREED contributions to the EU organic policy

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The ECOBREED project could initiate and support the development of organic seeds and breeding for organic agriculture/organic breeding in many European countries. The availability of good varieties for organic agriculture could be improved. The Farmers Participatory Trials (FPT) often used varieties from other countries that were not known before which increased the options for the farmers. The ECOBREED project provided many data about organic heterogeneous material (OHM). Therefore, it was the right time for the project. The results of OHM showed that populations are not better than pure line varieties automatically. Farmers also need some time to get used to populations especially if it is a new species. A first step with variety mixtures could be easier to understand for farmers.

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Protein-yield – an interesting metrics for organic varieties

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Yield and quality parameters like protein and gluten in wheat have a negative correlation to each other. Therefore, it is interesting for organic farmers to have a variety that provides a protein-yield with more than relative 100 because nitrogen is usually limited in organic farming. The Farmers Participatory Trials (FPT) in the ECOBREED project showed that some varieties demonstrate a tendency to a higher protein-yield (e.g., Capo, Wendelin, Alessio). Breeding for a higher protein-yield under organic conditions seems to be feasible. Both protein and yield must be within the range of farmer's expectations. In Hungary, the new population MV Bio2020 showed the highest protein-yields.

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Environmental stability of wheat populations in ECOBREED farmers participatory trials

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Some organic wheat populations were already available in the beginning of the ECOBREED project: Wakelyns (UK), Liocharls (DE) and MV Elit CCP (HU). They were grown in almost all wheat trials so many results of populations could be compared with the results for pure lines. In some literature it is mentioned that populations have a higher environmental stability (i.e. yield, quality parameters). In the ECOBREED trials, wheat populations often showed good results as they were more stable than average, but they were usually not the best ones in stability. Only in Hungary MV ELIT CCP showed the highest stability in yield. Our results show that breeding a good population is as complex as breeding a suitable pure line.

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Spectral responses of Slovenian potato varieties under water-restriction stress

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Potato as a crop plays an important role in ensuring global food security, underscoring the importance of adopting environmentally friendly and sustainable farming practices. Drought stress, a substantial abiotic factor affecting crop yields, especially in water-sensitive crops such as potatoes, can result in damage and yield reduction. The integration of modern technology and the application of innovative techniques can facilitate addressing this challenge. An illustration of such technology is provided by hyperspectral imaging, enabling precise monitoring of crop health and thereby contributing to more efficient potato cultivation practices. The spectral responses of three Slovenian potato varieties (*Solanum tuberosum* L.) within ECOBREED project, cultivated in a pot experiment within a controlled greenhouse environment and subjected to water-restriction stress over the course of one month, were investigated in this study. Hyperspectral imaging was employed in visible and near-infrared (VNIR, 400-1000 nm) as well as the shortwave infrared (SWIR, 1000-2500 nm) spectral regions to capture the spectral signatures of individual plants at three distinct time points. An F1 score of up to 81% was achieved in distinguishing various water regimes and varieties, demonstrating encouraging results. Precision and recall exhibited similar values, indicating that the model maintained a balanced performance during inference. The research highlights the effectiveness of hyperspectral imaging in assessing drought conditions in potato plants, providing valuable insights for future farming practices and breeding programs.

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Exploring High Throughput Tools for Decision Making in Potato

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As agricultural practices continue to evolve, there's an increasing need for efficient tools to optimize potato cultivation from planting to harvesting. The research centres along harnessing high-throughput tools like advanced sensing technologies, data analytics, and machine learning algorithms to refine decision-making processes in potato farming.

These tools facilitate swift and precise data collection and analysis, offering crucial insights into crop health by integrating environmental conditions and predicting yield potential. The research work also explores the Integration of high-throughput tools to empower farmers to make informed, real-time decisions, driving enhanced productivity, resource management, and crop quality.

For instance, remote sensing techniques were used to monitor crop growth and detect early signs of stress or disease, enabling timely interventions to minimize risks. The research study emphasise the pivotal role of selecting appropriate approaches and timing for data collection, amplifying the effectiveness of plant phenotyping. This allows advancements in potato phenotyping and disease detection while benefiting the broader agricultural sector through innovative image sensing and data analysis technologies. Further, the fusion of UAV-based phenotyping with machine learning approaches through predictive analytics allows us to build decision support systems which will aid farmers in forecasting and optimizing yield and managing inputs to foster profitability and sustainability in potato production.

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Research and utilization of buckwheat germplasm resources

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Buckwheat is an ancient crop traditionally used as a staple food in high-altitude areas. This gluten-free crop provides balanced amino acids, resistance starch, vitamins, and abundant bioactive flavonoid rutin. However, insufficient research and utilization of germplasm resources seriously restrict buckwheat genetic improvement. We collected buckwheat germplasms from 13 provinces of China and obtained wild germplasms with utilization value. Comparative genomics revealed varied copy number of flavonoid synthesis genes were responsible for different rutin content among Tartary buckwheat, common buckwheat, and golden buckwheat. Population genetics revealed Himalayan origin and northern China dispersed to Europe of Tartary buckwheat, as well as genetic variations responsible for different adaptability and floral development between Chinese and non-Chinese common buckwheat. Multi-omics analysis revealed the genetic basis of decreased flavonoids along with yield increase during Tartary buckwheat domestication, and flavonoids participate in Tartary buckwheat resistance to *Rhizoctonia solani*. Key genes responsible for yield and rutin content regulation were also identified. Using germplasms with special traits and molecular markers designed based on genetic variation, we bred a high yield Tartary buckwheat variety Zhongku No. 3 and a red flower common buckwheat variety Zhongqiao No. 21. This research will help promote the development of buckwheat breeding.

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Phenotyping of winter wheat genotypes - taking (some) of the shine off

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Accurate high-throughput phenotyping of crops enables the understanding of their responses to environmental conditions and identifying desirable traits. Drone-based multispectral imaging was combined with traditional methods of phenotyping to evaluate 12 winter wheat varieties in three competitive settings: (1) competition with common weed species, (2) competition with barley, and (3) a weed-free environment. From the 5-band orthomosaic images, 35 indices were calculated, yielding a total of 40 features. Partial Least Squares Discriminant Analysis (PLS-DA) was used as a feature extraction and dimensionality reduction method, as well as for regression analysis. The identification of varieties was achieved by combining PLS as a pre-processing step and support vector machines for classification (PLS-SVM). Overall PLS-SVM accuracy for identifying varieties was between 0.39 and 0.42, with accuracies for individual varieties reaching up to 0.95. A high specificity but low sensitivity was observed for individual varieties, indicating conservative model behaviour. PLS regression for biomass and yield prediction showed promising results, but the differences between the years required separate models be developed for each year. Multispectral imaging is a useful tool for high-throughput wheat phenotyping, but additional research is needed to quantify the effect of growing year and how to account for it in prediction models.

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Assesment of bioinsecticides against Colorado Potato Beetle (*Leptinotarsa decemlineata*, Coleoptera: *Chrysomelidae*) in laboratory and field conditions

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Laboratory and field trials were conducted in 2020 and 2021 to test four bioinsecticides (azadirachtin – product Neemazal, spinosad – Laser Plus, conidial suspension of two isolates of entomopathogenic fungus (EPF) *Beauveria bassiana*, *Bacillus thuringiensis* subsp. *tenebrionis* (Btt) – Novodor) and RNA interference (RNAi) against Colorado potato beetle larvae (CPB). The EPF were also combined with different doses of azadirachtin and spinosad to explore potential synergistic interactions between treatments. Treatment efficacy was determined by CPB larval mortality and a decrease in potato leaf consumption. A mix of both EPF isolates outperformed individual isolates and, combined with a 2% recommended dose of spinosad or 100% dose of azadirachtin outperformed those bioinsecticides alone, in laboratory assays. In field experiments in both years, treatments with spinosad (full and 20% dose, and spinosad + EPF) and azadirachtin alone showed significant larval reduction. In contrast, EPF, Btt and RNAi did not significantly control CPB larvae. All treatments except EPF in both years and RNAi in 2021 significantly reduced defoliation of potato plants. Despite significant differences in defoliation and larval reduction observed on individual plants, no significant differences in tuber yield were observed between treated and untreated field experimental plots, after a single (bio)insecticide application.

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