International Conference on

BREEDING AND SEED SECTOR INNOVATIONS FOR ORGANIC FOOD SYSTEMS

Online from Latvia

08-10 March 2021

By EUCARPIA Section Organic and Low Input Agriculture jointly with **LIVESEED, BRESOV, ECOBREED, FLPP projects** and **ECO-PB**

EUCARPIA

LIVESEED

AREI

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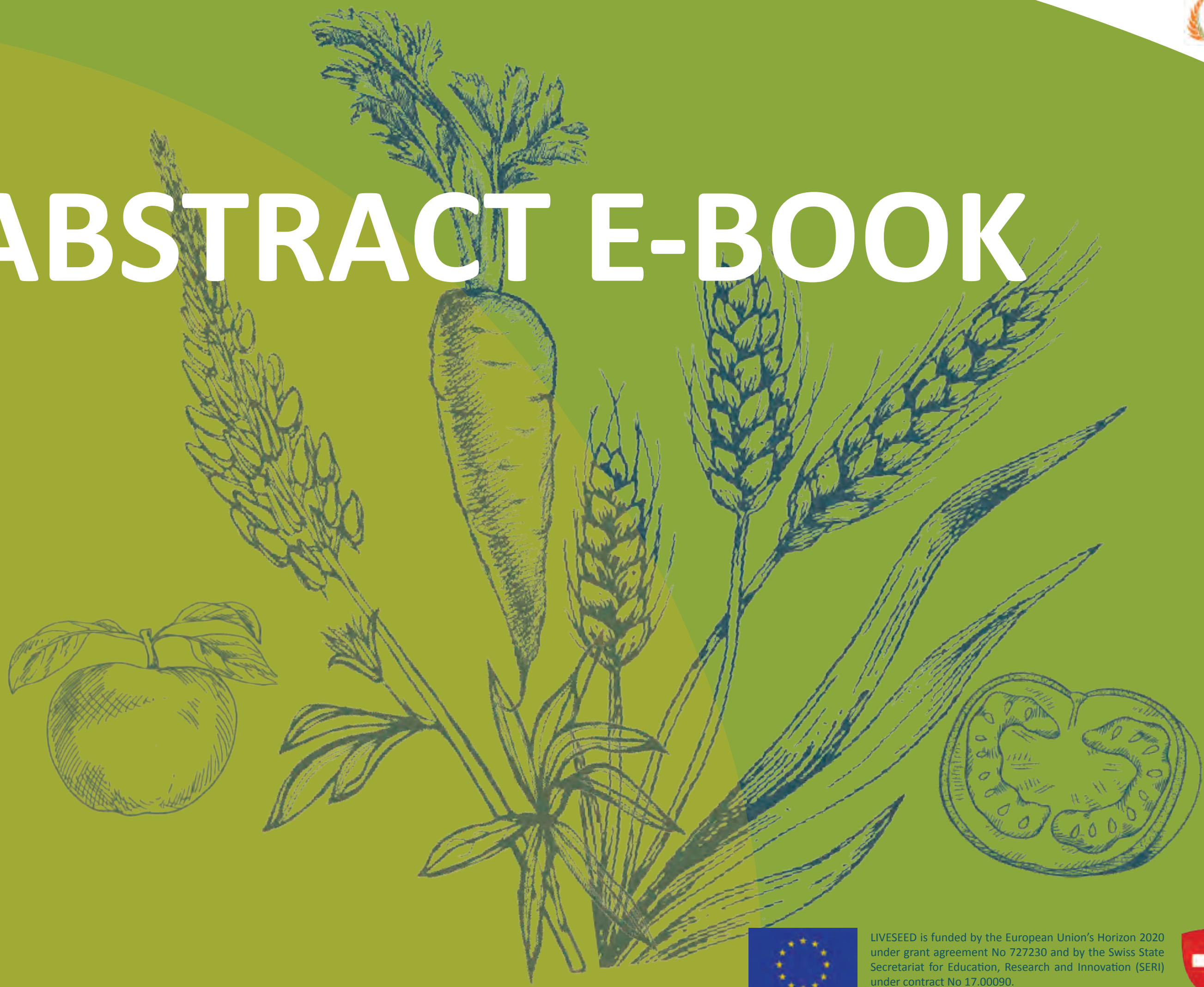
ABSTRACT E-BOOK



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Abstract e-book

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Scientific Committee

Local Organisers

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EUCARPIA
European Association for Research on Plant Breeding
Europäische Gesellschaft für Züchtungsforschung
Association Européenne pour l'Amélioration des Plantes

PREFACE

Dear participants of the conference 'Breeding and seed sector innovations for organic food systems' organized by the EUCARPIA Section Organic and Low Input Agriculture. It is a great pleasure for me to welcome you to this online conference jointly organised with the LIVESEED, ECOBREED, BRESOV and FLPP projects. This is the first Section Meeting in 2021 after we had a nearly complete conference lock down in 2020 due to the Covid-19 pandemic. Other Section Meetings are planned for this year which is important. And, there will be the General Congress in August which had to be postponed from last year. As you know, the aim of our organisation is to promote scientific collaboration in plant breeding research, mainly based on Section Meetings as yours. Therefore, I wish you a successful three days conference for exchanging new ideas and initiating new joint projects on the field of organic and low input farming.

Prof. Dr. Dr. h.c. Andreas Börner
EUCARPIA President

Dear EUCARPIA Section Organic and Low Input Agriculture members, like-minded and colleagues putting your efforts in other fields besides plant breeding!

This is the 5th conference of the Organic and Low Input Section since its establishment in 2007. Our section addresses the issues that are relevant to plant breeding for organic and low-input agriculture.
In addition, this is also the final conference of Horizon 2020-funded project LIVESEED "Boosting organic seed and plant breeding across Europe" that runs from 2017 to 2021. Relevant sister-projects BRESOV and ECOBREED are involved as well, along with two projects of Latvian national Fundamental and Applied Research program (FLPP).
This conference continues and broadens the issues discussed in 2018 in Witzenhausen, Germany on 'Breeding for Diversification' by including a range of research topics, from genetic resources to multi-actor and participatory approaches, socio-economic, market and policy aspects of organic plant breeding and seed production.
We, at the Institute of Agricultural Resources and Economics were planning to meet all of you in person in the small beautiful town of Cēsis in Latvia. Unfortunately the current pandemic has forced us to hold this conference on-line. Nevertheless, I hope that we will have a valuable exchange of research results, discussions and ideas for further cooperation!

Dr. Linda Legzdiņa
Chair of EUCARPIA Section Organic and Low Input Agriculture

LIVESEED – Improving the performance of organic agriculture by boosting organic seed and plant breeding efforts across Europe

Keywords: organic breeding, organic seed, cultivar testing, seed market and regulation, seed health

Organic agriculture is a rapidly growing sector and the European Commission is targeting to reach 25% organically managed farm land by 2030. The availability of high quality seed of a broad portfolio of cultivars and crops adapted to specific climatic, soil, and farming conditions is key for realizing the full potential of organic agriculture in Europe. However, the organic seed market is not meeting the required demand.

LIVESEED (2017-2021, www.liveseed.eu) is a Horizon 2020 project applying interdisciplinary and multi-actor approaches aiming to transform the organic seed and plant breeding sector. It is coordinated by IFOAM Organics Europe with FiBL-CH for scientific coordination and consists of 36 partners and 14 third linked parties from 18 European countries. The main goal is to reach 100% organic seed of cultivars suited for organic agriculture in order to improve competitiveness and integrity of organic production. LIVESEED covers the five main crop categories: legumes, vegetables, fruit trees, cereals and fodder crops, considering diverse cropping systems across Europe including mixed cropping and agroforestry. LIVESEED explored legal, technical, scientific, and socio-economic aspects that impact the use of organic seed from breeding to seed availability.

The goal of LIVESEED is to improve the productivity of the organic sector by boosting organic seed and plant breeding activities across Europe. Specific objectives are to:

- identify production and use of organic seed across Europe
- identify bottlenecks and provide approaches to harmonize the implementation of the rules for organic seed in the EU organic regulation (EC No 834/2007 and EC No 2018/848)
- develop an EU-wide router database tool for seed suppliers,
- develop a toolbox to describe organic heterogeneous material and provide testing protocols to facilitate the registration of organic varieties suitable for organic production (EC No 2018/848)
- develop and improve efficiency of cultivar testing with special focus on on-farm trials
- develop an organic seed health and quality strategy

- train on best practices for organic seed multiplication
- develop novel breeding concepts and deliver new breeding tools, and initiate new breeding activities and more efficient collaborations to close most urgent gaps for legumes, cereals, vegetables, fruit trees and fodder crops
- identify gaps and bottlenecks in the market of organic seeds, analyze business and governance models and develop incentives for the use of organic seeds
- study perception of organic consumers towards new genetic engineering techniques

This is accompanied by constant and targeted exchange with different stakeholder groups (breeders, seed companies, certification bodies, examination offices, national and European authorities, policy makers, farmers organizations, representatives of the organic value chain) and communication and dissemination activities to maximize impact of LIVESEED.

The European project LIVESEED (www.liveseed.eu) will help to establish a level playing field in the organic seed market across Europe, improve the competitiveness of the organic seed and breeding sector, and encourage greater use of organic seeds by farmers. Main results of LIVESEED achieved so far are summarized in a booklet on www.liveseed.eu under tools for practitioners.

LIVESEED received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 727230 and by the Swiss State Secretariat for Education, Research and Innovation (SERI) under contract number 17.00090. The information contained in this communication only reflects the author's view. Neither the Research Executive Agency nor SERI is responsible for any use that may be made of the information provided.

ECOBREED – Increasing the competitiveness of the organic breeding and farming sectors

Keywords: organic breeding, organic seed production, field crops

The organic sector has developed rapidly in the EU in recent years, not only in terms of the areas used for organic farming, but also in terms of the number of holdings and the total number of entities registered in the Union engaged in organic production, processing, and marketing. European H2020 project, ECOBREED is coordinated by the Agricultural Institute of Slovenia and includes 25 partners from 15 countries (AT, CN, CZ, DE, ES, GR, HU, IT, PL, RO, RS, SI, SK, USA, UK) and three continents. The ECOBREED project has been identified by the European Commission (DG AGRI and DG SANTE) as a strategically important project to achieve the objectives set out in Regulation (EU) 2018/848 of the European Parliament and of the Council on organic production and labelling of organic products. The new regulation seeks, among other things, for better access to organic seed on the market and greater heterogeneity of supply. Currently, the supply of organic seeds in the EU with a high level of genetic and phenotypic diversity is limited. This diversity is an important factor in successful development in organic farming, which contrasts with seed practices in the conventional, where a high degree of seed homogeneity is required.

The focus of ECOBREED is to improve the availability of varieties and seeds suitable for organic and low-input production. Activities focus on four plant species; wheat (*Triticum aestivum* L. and T. *durum* L.), potatoes (*Solanum tuberosum* L.), soybeans (*Glycine max* (L), Merr) and buckwheat (*Fagopyrum esculentum* Moench.). ECOBREED crop species were selected according to their potential contribution to increasing the competitiveness of the organic sector.

Common wheat is the most important crop used for human consumption in Europe and represents the largest organic crop area grown and represents the largest range of organic products available on the market. Potato is the most widely grown organic fresh produce crop in Europe. There is an urgent need to increase EU organic grain legume production to replace imported protein with a local production and growing demand for non-GM soybeans in Europe. Buckwheat is likely to provide key rotational benefits to an organic production system.

The project targets the improvement and availability of organic seed and varieties via extensive phenotyping and breeding activities with the support of an extensive training programme which will facilitate rapid technology transfer from the project (improved genotyping and phenotyping) into commercial practice. An important part of the project is the Participatory plant breeding (PPB) that enables scientists and farmers to improve conventional breeding by offering farmers the opportunity to select, develop and create varieties that best suit their needs, agronomic requirements and pedoclimatic conditions. PPB is a suitable alternative to organic production as it uses the expertise of farmers throughout the breeding process, allows selection in contrasting growing conditions and helps to develop local and regionally adapted varieties.

The project will develop (a) methods, strategies, and infrastructure useful for organic breeding, (b) new varieties with improved stress resistance, resource efficiency and quality, and (c) improved methods for producing high quality organic seed.

The specific objectives are to:

- Identify genetic and phenotypic variation in morphological, abiotic/biotic tolerance/resistance and nutritional quality traits that can be used in organic breeding.
- Evaluate the potential for genetic variation in enhanced nutrient acquisition.
- Evaluate the potential for increased weed competitiveness and control.
- Optimise seed production/multiplication via improved agronomic and seed treatment protocols.
- Provide farmers the opportunity to choose and develop varieties in their own environment that best suit their needs and conditions.
- Produce elite varieties for improved agronomic performance, biotic/abiotic stress resistance/tolerance and nutritional quality.
- Develop training programmes (improved genotyping and phenotyping) to facilitate rapid technology transfer from the project into commercial practice.
- Ensure optimum and rapid utilisation and exploitation of project deliverables and innovations by relevant industry and other users/stakeholder groups via extensive farm-based demonstration and dissemination activities.

The objectives of the project will be put into practice using an integrated and multi-disciplinary approach to increase the competitiveness of the organic/low-input breeding and farming sectors.

The research was funded from the European Union’s Horizon 2020 research and innovation programme under grant agreement No 771367 (ECOBREED).

BRESOV – Breeding for resilient, efficient and sustainable organic vegetable production

The BRESOV project, approved in the frame of the Programme H2020-SFS-07-2017 (GA 774244), deals with increasing the competitiveness of three important vegetable crops (broccoli, green beans and tomatoes) by providing climate-resilient cultivars addressed to organic vegetable farming systems.

Thanks to the wide involvement of stakeholders in genetic improvement, seed production and organic farming, the project aims to create a pipeline for the development of high quality organic seed production for breeders and farmers around the world. By the active involvement of farmers, advisory services, research institutes, breeding companies and food processors the ambition of the project is:

a) improving competitiveness of three important vegetable crops in organic production

b) extending the genetic basis of organic breeding for broccoli, snap bean and tomato

c) enhancing existing and newly developed varieties for organic vegetable production and increasing the plants' tolerance to biotic and abiotic stresses.

During the ongoing activities, 837 genetic materials of Brassica oleracea complex species (broccoli, cauliflower and related wild relatives) 496 of tomatoes and 675 of green beans were genotyped and phenotyped for indentifying traits of interest for organic agriculture such as biomorphological characteristics of the plants, resistance to water, saline and thermal stresses, senescence induced by darkness, nitrogen and water use efficiency, resistance to black rot, downy mildew, Alternaria spp. and other key pathogens of these crops. Particular attention has been paid to detect the content of the antioxidant compounds into the produce matrices, such as glucosinolates, polyphenols, carotenoids, in addition to protein content and the main organoleptic characteristics of the product (eg sweetness, acidity, color).

In relation to high quality organic seed production and to the evaluation of the pre-breeding lines, in organic farms in various European countries characterized by different pedoclimatic conditions, there are various activities in progress that includes evaluating the influence of crop density, of the nutritional compounds allowed in organic farming, and of the methodology for adopting new organic farming tools such as the natural extracts and the bioactive agents for controlling pests and diseases.

The results acquired during the first two years of the BRESOV project already allow the consortium to support the growing demand for organic vegetables, offering the opportunity to combine research results with the requests of growers and consumers of the reduction of chemical contaminants, both into the soil and in food products. The ongoing selection of the elite breeding lines of broccoli, snap beans and tomatoes, more resistant to climate change and to pests and diseases, will render organic production more competitive and attractive for farmers throughout Europe and outside the European Union.

The BRESOV project is supported by 22 partners from 10 European countries, 2 EU associate countries (Switzerland, Tunisia), and 2 Extra-EU countries (China and South Korea), and has adopted multi-actor and interdisciplinary approaches placing particular emphasis on the needs of several European and foreign stakeholders involved in breeding, seed and organic farming activities.

Genetically diverse populations of self-pollinating cereals for organic farming: agronomic performance, effect of environment, and improvement techniques

Keywords: organic farming, crop breeding, composite cross populations (CCP), genotyping, molecular markers, spring barley, spring and winter wheat

The research aim of the project carried out by Institute of Agricultural Resources and Economy (AREI, Latvia) during 2018-2021 is to investigate agronomic performance, efficient improvement techniques and changes due to environmental effects in genetically diverse populations, which are a potentially significant alternative to traditional varieties for self-pollinating cereals in environmentally friendly agriculture. This work is being continued from another local project, which first started to study genetically diverse populations in Latvia. Agronomic traits important for organic farming as yield and its stability, competitive ability against weeds, nutrient use efficiency, disease resistance/tolerance and grain quality is being assessed for spring barley and wheat composite cross populations (CCPs) in field trials under organic and conventional crop management systems. The effect of repeated multiplication and cultivation in different environments on CCP agronomic and morphological traits and genetic diversity using molecular tools is being evaluated. Development and improvement of breeding techniques includes elaboration of molecular marker, application of negative mass selection for disease resistance/tolerance enhancement, line selection from CCPs for building mixtures, and crossing of CCP to perspective/local genotypes. The material of spring barley CCPs created in Latvia, barley and wheat CCPs from abroad and newly created CCPs are being studied. Testing of selected populations in larger scale on-farm trials is also going one. Results will ensure new knowledge in agriculture and biology as well as information for authorities in order to facilitate registration and marketing system establishment for genetically diverse populations.

This research is funded by the LATVIAN COUNCIL OF SCIENCE, grant number lzp-2018/1-0404, acronym FLPP-2018-1.

Potato breeding for low input and organic farming systems: nitrogen use efficiency and quality aspects of potato protein

Keywords: NUE, nutrition management, phenotyping, patatin, NIRS

Potato crop requires soil that is rich in nutrients or high doses of fertilizers normally have to be applied to obtain high and qualitative tuber yield.

According to EU legislation, nitrogen (N) applications have to be limited in EU and also in Latvia. Evolving new potato varieties with improved nitrogen use efficiency (NUE) for potato production can help improving nutrition management and reducing N emissions thus minimizing environmental impacts. Varieties with improved NUE, especially under limited N availability, can foster the advancement of low input and organic farming systems. High-quality proteins (incl. patatin) present in potato can be used for feed and food purposes thus increasing added value to potato and processing by-products.

Screening for NUE under field conditions is time-consuming and labor-intensive, therefore more efficient methods for NUE estimation are required.

The aim of the three-year (2020 - 2022) research project is to investigate new techniques for potato breeding for NUE and to estimate NUE effect of the genotype on potato protein quality.

During the project a number of NUE related traits both under *in vitro* and field conditions will be assessed and results obtained in both systems compared to find possible predictive markers for estimation of NUE under *in vitro* conditions. Field trials will be carried out in different locations and farming systems (conventional and organic) for more comprehensive results. Laboratory investigations will be carried out in AREI, Priekuli branch. If a reliable marker will be detected, it will serve as an innovative and more efficient phenotyping method for NUE and will greatly improve the potato breeding process.

Relationships between levels of protein patatin and NUE estimation in potato genotypes will be assessed. As a result, the understanding of the effects of NUE of genotypes on the abundance of patatin in potato tubers will be facilitated. Patatin detection methods will be adopted. New parameters (N, protein) will be calibrated to NIRS for express analysis to accelerate further research on NUE and breeding.

The project is funded by Latvia Council of Science in the frame of Fundamental and applied research projects (FLPP) program.

European Association for Research on Plant Breeding
Europäische Gesellschaft für Züchtungsforschung
Association Européenne pour l'Amélioration des Plantes

EUCARPIA – European Association for Research on Plant Breeding

EUCARPIA aims to promote scientific and technical co-operation in the field of plant breeding in order to foster its further development. To achieve this purpose, the Association arranges and sponsors meetings to discuss general or specific problems from all fields of plant breeding and genetic research. Activities with a predominantly commercial interest are excluded, as EUCARPIA is a non-profit organization.

EUCARPIA organizes section and working group meetings throughout Europe each year. During these meetings devoted to particular crops or cross-cutting topics, specialized up-to-date knowledge and methodology are exchanged among leading scientists and conveyed to practical plant breeders.

Every four years, the General Congress is held together with the general assembly. These congresses are an opportunity for all EUCARPIA members to discuss subjects of a wider interest. They provide a forum for presentation of the problems and challenges which plant breeding faces today and in the future. The next congress takes place 22 till 27 August 2021 in Rotterdam, the Netherlands.

Founded in 1956 and officially seated in Wageningen (The Netherlands), EUCARPIA provides considerable impact on improving international contacts in plant breeding research for nearly 60 years.

EUCARPIA is offering membership for scientists and researchers of all disciplines related to plant breeding.

The work of EUCARPIA is organised in 11 sections and one of them is section Organic and Low-Input Agriculture.

ECO-PB – European consortium for organic plant breeding

Keywords: organic breeding, organic seed, cultivar testing, policy recommendations

The European Consortium for Organic Plant Breeding (ECO-PB) founded 20th April 2001 in Driebergen (NL) in order to

- provide a platform for discussion and exchange of knowledge and experiences among organic breeders, seed producers and researchers
- initiate and support of organic plant breeding programs and strengthen networks among partners
- develop of scientific concepts of an organic plant breeding
- provide independent, competent expertise to develop standard setting with respect to organic plant breeding
- represent the organic plant breeding and organic seed sector on European level

ECO-PB is committed to the principles of organic agriculture as laid down in the IFOAM Basic Standards and EU Regulation (EEC) 2092/91 and is member of IFOAM Organics International, IFOAM Organics Europe, TPOrganic and founder of the international IFOAM Seed Platform. ECO-PB has observer status in the technical meetings of CPVO and is acknowledged organisation of the EU transparency register.

ECO-PB offers full membership to all organisations that are actively and predominantly engaged in the development and promotion of organic plant breeding or organic agriculture and supporting membership to individual persons predominantly engaged in organic agriculture and complying with the objectives of the association. Presently ECO-PB consists of 15 full member associations and 27 associated members spread across Europe (www.eco-pb.org).

Main activities of ECO-PB are to

- carry out and support meetings and workshops on legal, political, technical, socioeconomic aspects related to organic seed and plant breeding
- work out a sound concept based on principles of organic agriculture and systems-based breeding as a basis for organic plant breeding strategies
- promote research topics on organic breeding and set up and participate in research projects and networks on organic plant breeding

- provide discussion paper on plant breeding issues to support the decision making process in European and international level
- find alliance with other organizations and represent our members in political and stakeholder dialogs
- participate in consultations, workshops, stakeholder and policy meetings in order to promote the interests of our members
- provide a platform for young breeders supported by experienced mentors
- collect training material on organic seed and plant breeding from members and partners of LIVESEED, ECOBREED and BRESOV
- support the Preconferences Organic Seed Ambassadors of the Organic World Congress in collaboration with the Organic Seed Alliance from the USA in September 2021 in Rennes https://owc.ifoam.bio/2021/en

Institute of Agricultural Resources and Economics

The Institute of Agricultural Resources and Economics (AREI), with more than 100 years of history, is the leading field crop breeding institute in Latvia.

The research directions of the institute are related to crop genetics and breeding, crop management and agroecology for sustainable farming, provision of quality requirements of raw materials for processing, as well as development of sustainable rural space, economic analysis for agriculture, food production and fisheries. The institute has two scientific departments – the Department of Crop Research and the Department of Bioeconomics, which carry out research in the fields of agriculture, agrarian economy, and rural development, carrying out more and more interdisciplinary research projects. AREI regularly participates in international research projects, national research programs, research of national importance, as well as perform collaborative research with farmers, merchants and municipalities. Part of research is related to the provision of functions delegated by the government. Crop Research Department carries out significant research in the development and improvement of crop breeding methods, as well as in the study of genes that determine important traits, especially resistance to biotic and abiotic factors. An important task for AREI breeders is the maintenance and evaluation of plant genetic resources.

In the period from 2003 to 2006, Ministry of Agriculture of Republic of Latvia (MoA) funded trials aimed to develop the value for cultivation and use (VCU) testing protocols in Latvia (at present, the Latvia University of Life sciences and Technologies ensures the assessment of the VCU tests of organic plant varieties). During this period, all locally bred cultivars of cereals, potatoes, pea and grasses in the plant variety catalogue (PVC) were tested for their suitability for organic farming. Since then, trials under organic conditions have been possible and well-performing varieties are marked as “Bio” in the national PVC. Since 2003, AREI is testing varieties for their suitability for organic farming. AREI carries out field trials with potatoes, cereals (spring barley, winter rye, winter and spring wheat etc.), field peas and grasses. Six potato varieties, four field pea varieties, five spring barley varieties, two oat and one wheat variety, as well as several varieties for a number of grass species, bred by AREI have been officially recognized as suitable for organic farming.

In 2020, the total agricultural area of AREI was 510 ha, of which 50 ha was organically certified area used for plant breeding, field trials, and seed production. AREI has the organic breeding program. The identification and application of genetic markers of traits important for new varieties is becoming usual for evaluation of breeding material in breeding programs. Currently the breeding for organic farming is carried out for several field crops: spring barley, faba bean, spring pea, winter and spring wheat, and spring oat, and is funded by the MoA. Besides organic breeding and variety testing, AREI is involved in projects aimed to research on growing technologies under organic conditions. These trials include not only common field crops, but also less common species in Latvia such as narrow-leaf lupin, quinoa and soybeans. AREI successfully participated in EC Temporary Experiment on marketing of heterogeneous populations using spring barley composite cross population 'Mirga'. AREI is also organic seed producer for potatoes, red clover, winter and spring wheat, winter rye, field peas, and buckwheat. AREI performs research in agroecology, maintenance of soil fertility, weed management in both integrated and organic farming.

ORGANIC FARMING IN LATVIA

The sector of organic agriculture in Latvia is continuously developing, involving more and more new enterprises. The number of certified organic enterprises in Latvia reached 4450 in 2019, and area under organic farming in Latvia was about 14% from utilised agricultural area or 290 thousand ha. A total of 262.5 thousand ha of land were converted to organic, but 27.5 thousand ha were still undergoing conversion. Compared to 2018, the organically certified area had grown by 6.4 thousand ha that is about by 2.2%.

In 2019, the major part of organically certified fields was under cereal crops covering 58.5 thousand ha, most of which were oats (23.5 thousand ha) and wheat (15.5 thousand ha). Organically certified potatoes were grown on 1486 ha, organic vegetables – 423 ha, most of which were pumpkins (137 ha). The most popular organically grown berries and fruit trees in Latvia were black currants (925 ha), apple trees (712 ha) and sea buckthorn (399 ha). In total, organic fruits and berries were grown on 3053 ha.

Compared to 2018, organic grain production increased by 32% in 2019, reaching 117 thousand tonnes. Quantity of produced vegetables, potato and eggs was also higher. However, the milk production decreased by 6.2 thousand tonnes, less meat, fruit and berries were produced.

Organic farming in Latvia is characterized by multisectoral production. Main sector of animal husbandry in organic farms is milk production. Sheep farming has also become popular.

During last years about 20 organic farms in Latvia produce certified organic seed. Mostly organic cereal seed, especially oat and barley, is produced. Production of certified organic seed material for red clover, timothy, and buckwheat is also significant. The amount of produced organic certified seed covers only 3.2% of organic seed demand in the country. Home-saved organic seed material is still widely used. More than two thousand derogations allowing use of conventional seed or planting material in organic farms are granted every year.

Latvia participates in Temporary experiment (Commission Implementation Decision 2014/150/EU) for marketing of heterogeneous seed material of cereal species. Heterogeneous barley population 'Mirga', which has been developed in AREI, is grown in four organic farms.

THE ASSOCIATION OF LATVIAN ORGANIC AGRICULTURE

The Association of Latvian Organic Agriculture (hereinafter - ALOA) was founded in 1995. It is a legal, professional, non-governmental organisation that brings together ~1500 producers, traders and processors of organic products: milk, meat, honey, fruit, vegetable and cereals, processors, traders and supporters of organic food in Latvia. The association unites 11 regional branches and representatives of 11 areas of industries.

ALOA is an important partner and representative of organic farms and companies to the government and the state institutions in charge of planning and supervision of the agricultural sector.

ALOA is actively working with various departments of the Ministry of Agriculture, making proposals for the sector development.

Key areas of cooperation:

- Implementation of the Latvia's Rural Development Programme 2022-2027;
- Implementation of the EU common agricultural policy 2022-2027;
- European Green Deal with its two strategies *Biodiversity Strategy for 2030 and Farm to Fork*;
- Organic farming supervision and control matters.

ALOA cooperates with other public organisations in the areas of agriculture and environment: Farmers Federation, Latvian Fund for Nature, The World Wildlife Fund, Latvian Beekeeping Association and others.

Objectives of the association

To bring together those working in the organic farming industry and supporters of environmentally friendly farming and users of organic products.

To build market policies and find market opportunities for sales of organic food products.

1. To provide learning opportunities for organic farmers.
2. To raise public awareness about the importance of natural products in being healthy.
3. To promote green and sustainable farming methods.
4. To represent members' interests in state and local government institutions as well as non-governmental organisations.
5. Organic farming policy making.

In 2020 ALOA started publishing an informative magazine "BIOLOĢISKI" with the aim to strengthen organic agriculture in Latvia.

CONFERENCE PROGRAM

MONDAY, MARCH 8TH 2021

08:30 Open access

08:50 Technical instruction

09:00 **Welcome addresses**

09:30 **L. LUTTIKHOLT – Transforming food systems, transforming breeding**

SESSION 1 – EXPLORING UNDERUTILIZED GENETIC RESOURCES (moderated by Vladimir Meglič)

10:00 S. GORITSCHNIG – EVA - European evaluation networks harnessing crop genetic diversity present in European genebanks

10:20 E. FLIPON – Mobilising diversity for minor cereals in western France

10:35 D. JANOVSKÁ – Exploring buckwheat genetic resources for organic breeding

10:50 A. KRONBERGA – Domestification potential of Latvian local medicinal and aromatic plants genetic resources

11:05 *Coffee break*

11:20 J. PROHENS – Characterization under low N conditions of advanced backcrosses of eggplant (*S.melongena*) with introgressions from *S.elaeagnifolium*

11:35 C. ARNCKEN – Pre-breeding of white lupin for anthracnose tolerance

11:50 F. BRANCA – Response of different genotypes of *Brassica oleracea* var. *Gongylodes l*. to drought stress

12:05 General discussion

BREAKOUT POSTER SESSIONS

12:30 Topic 1 – **Exploring underutilized genetic resources** (moderated by Ferdinando Branca)

Topic 3 – **Breeding for culinary and nutritional quality** (moderated by Edith Lammerts van Bueren)

13:15 *Lunch*

SESSION 2 – BREEDING FOR DIVERSITY (moderated by Edwin Nuijten)

14:15 P. MENDES MOREIRA – LIVESEED: Enhancing resilience at systems level through breeding for diverse cropping systems

14:35 D. DESCLAUX – Why is it so difficult to breed for sustainable organic food system? Some examples on cereals

14:50 G. VAN FRANK – Participatory on-farm breeding for diverse and adapted wheat mixtures

15:05 E. FLIPON, V. CHABLE – Comparing two selection strategies of bread wheat diversified populations adapted to organic farming

15:20 I. LOČMELE – Assessment of spring barley variety mixtures and populations in comparison to homogenous varieties

15:35 N. MOUTIER – Breeding for wheat-pea mixtures: are the traits of pea varieties in sole crop predictive of their behaviour in mixture?

15:50 M. PETITTI – Evolutionary participatory tomato breeding in Italy for organic agriculture

16:05 General discussion

16:30 *Coffee break*

SESSION 3 – BREEDING FOR CULINARY AND NUTRITIONAL QUALITY (moderated by Edith Lammerts van Bueren)

16:45 J. DAWSON – Scaling up participation in breeding for flavor: engaging farmers, gardeners, culinary professionals and consumers

17:10 E. NUIJTEN – Breeding for quality: lessons learned on three vegetable crops

17:25 J. ZYSTRO – A case study in efficient methods for evaluating and selecting for flavor in organic sweet corn breeding programs

17:40 General discussion

18:00 *Coffee break*

BREAKOUT SESSIONS

18:15 – 19:15	Posters, Topic 2 – **Breeding for Diversity** (moderated by Pedro Mendes Moreira)	**Contribution of genetic resources for breeding for diversity** (moderated by Ferdinando Branca and Vladimir Meglič)	**Discussion on impact of new breeding techniques** (moderated by Monika Messmer)

TUESDAY, MARCH 9TH 2021

08:30 Open access

08:50 Technical instruction

SESSION 4 – LIVING SOIL - PLANT INTERACTION (moderated by Pierre Hohmann)

09:00 G. BERG – Sowing the right seeds for sustainable agriculture

09:25 A. WOLFGANG – Bacterial seed communities in sugar beet are influenced by propagation site and genotype

09:40 F. TROGNITZ – Seed endophytes isolated from soybean and their application for biocontrol and plant growth stimulation

09:55 P. KUSSTATSCHER – Pumpkin breeding shapes the seed microbiome

10:10 M. BIGET – Spatio-temporal heterogeneity in the root-microbiota of grape vine: a microbial terroir in vineyards

10:25 T. TAKÁCS – Physiological and growth responses of pea intercropped wheat cultivars

10:40 General discussion

11:00 *Coffee break*

SESSION 5 – ORGANIC PRODUCTION OF HIGH QUALITY & HEALTHY SEED (moderated by Ambrogio Costanzo)

11:15 F. REY – Improving cultivar testing, seed multiplication & health for high quality seeds for the organic sector: overview of LIVESEED outcomes

11:35 M. COLLEY – State of organic seed production in the United States

11:55 S. KLAEDTKE – From seed to plant health – a broader picture

12:10 A. BORGEN – Seed treatments to control common bunt

12:25 S.P.C. GROOT – Carrot seed vigour, field emergence and tolerance to the damping-off pathogen *Alternaria radicina*

12:40 H. CARDOSO – Calorespirometry – a promising phenotyping tool to assess seed viability based on respiratory parameters

12:55 General discussion

13:15 *Lunch*

BREAKOUT POSTER SESSIONS

14:15 Topic 4 – **Living soil - plant interaction** (moderated by Gabriele Berg)

Topic 5 – **Organic production of high quality & healthy seed** (moderated by Federic Rey)

SESSION 6 – MULTI-ACTOR & PARTICIPATORY APPROACHES (moderated by Veronique Chable)

15:00	N. ENJALBERT – Simplify collaboration, amplify results: facilitating a diverse seed system with a collaborative digital platform
15:20	F. REY – Frugal, multi-actor and decentralised cultivar evaluation models for organic agriculture: methods, tools and guidelines
15:35	M. COLLEY – The ripple effect of participatory plant breeding: a case study in US organic sweet corn
15:50	*Coffee break*
16:05	A. RODRIGUEZ-BURRUEZO – Participatory breeding in tomato in southern Europe in the frame of organic farming: approaches, plant populations, results and lessons learned
16:20	P. ANNICCHIARICO – Genome-enabled, farmer-participatory selection: making edges meet
16:35	K. ISAACS – A network approach for large-scale participatory variety-by-context testing: results from sorghum variety trials in Mali
16:50	General discussion
17:20	*Coffee break*

BREAKOUT SESSIONS

17:35 – 18:35	Posters, Topic 6 – **Multi-actor & participatory approaches** (moderated by Bernd Horneburg)	**Demonstration of Seedlinked** (moderated by Nicolas Enjalbert)	**Potential of participatory breeding** (moderated by Micaela Colley)

WEDNESDAY, MARCH 10TH 2021

08:30 Open access

08:50 Technical instruction

SESSION 7 & 8 – SOCIO-ECONOMIC, MARKET AND CONSUMER ASPECTS OF SEED SYSTEMS (moderated by Raffaele Zanoli)

09:00 S. PADEL – Organic seeds and varieties: can the market deliver?

09:25 E. WINTER – Assessment of policies aiming at boosting organic seed use

09:40 S. ORSINI – Appraisal and usage of organic seed in Europe from organic farmers' perspective

09:55 J. KOTSCHI – Funding organic plant breeding and the potential impact of open source seed systems

10:10 *Coffee break*

10:25 E. CUBERO DUDINSKAYA – European organic consumers' attitudes and acceptance of new plant breeding techniques for crops

10:40 H. WOLTER – Consumer perceptions and evaluations of the Open Source Seeds License

10:55 C. MEIER – Consumer preferences for healthy minor cereals

11:10 General discussion

11:40 *Coffee break*

11:55 **Video excursion to Latvian organic farms**
Promotion video on organic breeding
Announcements regarding next events

BREAKOUT POSTER SESSION

12:30 Topic 7 & 8 **Socio-economic, market and consumer aspects of seed systems** (moderated by Stefano Orsini)

Topic 10 **Sustainability** (moderated by Giuseppe Timpanaro) **Selection of best posters by participants**

13:00 *Lunch*

SESSION 9 – REGULATORY AND POLICY OPPORTUNITIES (moderated by Bram Moeskops)

14:00 E. GALL, M. SOMMER – New rules on seeds in the new EU Organic Regulation

14:20 K. MEYER – Collecting commitment in 10 EU member states – the organic seed declaration

14:35 M. RAAIJMAKERS – The need for national roadmaps to come to 100% organic seed

14:50 M.H. BERNICOT – Assessing varieties for organic farming: what contribution from evaluation in conventional farming?

15:05 General discussion

15:25 *Coffee break*

SESSION 10 – SUSTAINABILITY (moderated by Monika Messmer)

15:40 A. RIAR – Participatory organic cotton breeding approach to achieve sustainable development goals

16:00 E. NUIJTEN – Implementing the systems-based breeding concept

16:15 A. SCUDERI – Sustainability assessment of broccoli (*Brassica oleracea* var. *Italica*) production with deficit irrigation system in Sicily

16:30 R. LEITÃO – Successional agroforestry systems for Europe: the Portuguese example

16:45 General discussion

17:00 **Winners of the poster contest and quiz**

17:10 **Closing of the conference**

17:40 *Break*

17:45 **EUCARPIA Organic & Low-input section members meeting**

TRANSFORMING FOOD SYSTEMS, TRANSFORMING BREEDING

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Keywords: sustainable food systems, transformation, coherent policies

Sustainable agriculture and food systems need to provide sufficient and nutritious food for all, while minimizing environmental impact and enabling producers to earn a decent living. Most agree that agriculture and food systems urgently need to change to make progress on several SDGs while staying within planetary boundaries (Willett 2019). The UN secretary General convenes the 2021 Food Systems Summit to launch bold new actions to transform the way the world produces and consumes food, delivering progress on all 17 SDGs.

Organic agriculture is based on the principles of Health, Ecology, Fairness and Care (Luttikholt 2007). The ten elements of Agro-Ecology overlap with these principles and point to the same direction for development of agriculture for it to be truly sustainable. Scientists and practitioners in these sectors have recognized since long that the self-regulatory ability of sustainable farm ecosystems need specific functional biodiversity at farm, field and crop level (Lammerts van Bueren 2002). This requirement is not served with seeds bred for high-input agriculture. Moreover, the ethical values and the integrity approach (Verhoog 2007) of organic and agro ecological agriculture, require careful consideration of compatibility of breeding techniques (IFOAM – Organics International 2017(1)). At the same time, (certified) organic seed of suitable varieties are not always available, which might pose a threat to the credibility of the organic sector (IFOAM – Organics International 2011). The revised EU organic regulation stipulates phasing out of derogations to the use of non-organic plant reproductive material latest by 2036, therefore invites for a clear transition to bridge the gap.

The organic agriculture movement, with its statement Organic 3.0, aspires to get out of a niche position and inspire mainstream agriculture to enable the much-needed widespread uptake of truly sustainable farming systems (IFOAM – Organics International 2017(2)). As such, it offers its practices, traditions and experiences to all farmers. Likewise, organic seed breeding and propagation not only works to serve the organic sector. Both the innovative breeding processes and the available outputs are a contribution towards the necessary transformation of all agriculture.

The policy, and so the implied economic, context needs to change to promote a transition of all agriculture towards more sustainability. The European Green Deal sets a (legally non-binding) framework and goal for support for transformative systems. However, for such framework to work for organic and sustainable agriculture and so plant breeding therefor, policies need not only support transition to organic agriculture. Most importantly policies need to be coherent and work at all levels. Allowing commercialization of organic heterogeneous material in the EU organic regulation is one such example. Which need to go hand in hand with providing right incentives for improvements and raising legal requirements and general industry norms (Eyhorn 2019), like banning most hazardous chemical pesticides such as glyphosate. This coherent policy package should get underpinned through true or full cost accounting (IFOAM – Organics International 2019) which implies accounting for all inherent negative effects of plant breeding for high-input agriculture and food systems. Transparency in the organic seed market will further simplify access to appropriate seeds, which might stimulate further demand. Consequently, production of high quality and healthy organic seeds fitting and contributing to a benevolent agro-ecological production system, contributing to the public good, will therewith be a rewarding activity, in all aspects.

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Exploring underutilized genetic resources

EVA – EUROPEAN EVALUATION NETWORKS HARNESSING CROP GENETIC DIVERSITY PRESENT IN EUROPEAN GENEBANKS

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Keywords: characterization, evaluation, EVA, EURISCO, crop genetic resources, public-private partnerships

The European Cooperative Programme for Plant Genetic Resources (ECPGR) aims at ensuring the conservation and utilization of plant genetic resources in Europe through collaborative activities with relevant stakeholders. Through a series of projects, and with the support of the German government, a European Evaluation Network (EVA, https://www.ecpgr.cgiar.org/european-evaluation-network-eva) was established in 2019. EVA brings together different stakeholders in public-private partnerships to jointly generate characterization and evaluation data on crop accessions present in European genebanks, which are often poorly characterized and consequently underutilized.

Crop-specific EVA networks are intended to function as self-sustaining networks with repeated cycles of 1) selection of accessions from genebanks, 2) multiplication of seed, 3) evaluation by partners in multilocation trials across Europe, 4) genotyping of all tested accessions, 5) data analysis and inclusion in the European Search Catalogue for Plant Genetic Resources (EURISCO) and accessions included in the European Genebank Integrated System (AEGIS), as appropriate. All activities within the EVA networks are intended at the pre-competitive stage, to increase our knowledge about valuable traits of publicly available crop germplasm, with a view to introducing these into public and private breeding programs.

At this moment, five crop-specific networks are operational, working on carrot, lettuce, pepper, maize, wheat and barley. Together, the EVA networks currently consist of 92 partners from 31 countries within the ECPGR region, including 26 genebanks, 33 research institutes and 49 breeding companies. Among the breeding companies we count a number of organic seed producers, highlighting their interest in discovering and testing new materials for direct use or breeding within the European genebank catalogues.

Using standardized protocols and templates, partners collect evaluation data from different environments across the continent. Priority traits of the different networks include biotic and abiotic stress traits as well as agronomic characteristics that will be important in broadening the genetic basis of crops and developing crops suitable for diverse agro-ecologies and able to cope with the challenges of a changing climate.

Initial results from some networks are promising, as several accessions with interesting traits have already been identified and will be further characterized. Through participation in the Horizon 2020 project AGENT (https://www.agent-project.eu/), the EVA Wheat and Barley network extends its evaluation activities to also include an organic farmers' network coordinated by the Italian Association Rete Semi Rurali who will be evaluating material specifically for organic growers' purposes.

Providing a framework for the establishment of successful public-private partnerships, EVA promotes sustainable use of Plant Genetic Resources for Food and Agriculture (PGRFA) to facilitate adaptation of European agriculture to climate change and to contribute towards achieving related Sustainable Development Goals (SDGs).

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MOBILISING DIVERSITY FOR MINOR CEREALS IN WESTERN FRANCE

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Keywords: diversity, variety mixtures, adaptation

The current food system and agricultural practices are based on low diversity, in terms of number of cultivated species and of cultivars. This increases the vulnerability of the production systems as it reduces adaptability to the local conditions and to climate change (Fehér J. et al., 2019).

To solve this problem, farmers, actors of the food system and researchers from different organisations are implementing collective agrobiodiversity management projects where they mobilize cultivated biodiversity adapted to the organic farming principles (most of it coming from gene banks).

Currently, a widely used technique is to multiply each accession in pure line and to describe it. But this is very time consuming and moreover, the accessions are highly homogeneous, poorly described in the gene banks' databases and are too numerous to be mobilized with this methodology.

The ITAB-INRAE team proposes a methodology based on numerous demands of farmers who needed more intra-specific diversity for underutilized cereals. It mobilises an important diversity and speeds the breeding process for farmers, by creating Diversified Oriented Populations (DOP). Those populations result from the mix of different accessions that have been multiplied and described from two to four years in experimental platforms. They are then mixed to create populations that correspond to specific criteria requested by each farmer involved (phenotypic traits).

Our hypotheses are that the DOP populations have a great adaptation capacity due to their important diversity and that the populations' morphological characteristics described and chosen by the farmers may be easily conserved from one generation to the next ones.

This methodology is then an additional tool to spread and use diversity for organic agriculture. It was implemented during DIVERSIFOOD project and continued in the framework of LIVESEED. Three species were used to set up the method: rivet wheat, spelt and oat.

Rivet wheat DOPs have already been distributed for two years and from now on, the farmers are satisfied with the method and we wish to develop it for more species.

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EXPLORING BUCKWHEAT GENETIC RESOURCES FOR ORGANIC BREEDING

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Keywords: common buckwheat, genetic resources, phenotyping, breeding

In the past, common buckwheat was frequently grown in many European countries. Nowadays its cultivation is marginal, however constantly increasing since the 1990s (FAOSTAT, 2020) due to an increased demand for gluten-free, as well as organic and locally produced food. However, there are sparse common buckwheat breeding programmes in Europe. In order to assist buckwheat breeders, phenotyping buckwheat genetic resources stored in germplasm collections and selecting genotypes best suited to the various European conditions is of paramount importance.

A set of 54 buckwheat genotypes, originating from European and world seed collections was phenotyped in field trials in Austria, Czech Republic and Slovenia according to common descriptors. In total, more than 30 characteristics were evaluated (e.g. morphological and phenological traits, etc.). Additionally, other characteristics, e.g. the antioxidant activity, the total phenolics and the rutin content were analysed. According to initial results, there were clear differences for several traits between the countries showing a genotype-environment interaction. Similarities among the genotypes were also found. Because of the variability observed but also G×E for several traits, the further evaluation is necessary to identify genotypes with stable expression/performance of demanded traits. The phenotypic evaluation was repeated in 2020 to confirm the results obtained.

Acknowledgements

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DOMESTIFICATION POTENTIAL OF LATVIAN LOCAL MEDICINAL AND AROMATIC PLANTS GENETIC RESOURCES

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Keywords: medicinal and aromatic plants, domestification, genetic resources

Demand for medicinal and aromatic plants (MAPs) is increasing due to growing human needs, commercial trend and increasing popularity for natural-based, environmentally friendly products (Allkin et al., 2017). Around 70,000 plant species are in use for medicinal purposes (Lohwasser and Weise, 2020). However, 60-90% of the medicinal and aromatic plants in Europe are collected in the wild and thus it leads to over-exploitation of many wild populations (Schippmann et al., 2002) Increasing number of MAP species in cultivation would be a benefit for relieve the pressure on natural populations and provides processing industries with available, predictable, and stable supply.

The selection of genotypes with commercially desirable traits from the wild may offer opportunities for the development of the MAP species as a crop. Different biological features or ecological requirements (low germination rates, special soil and shadowing requirements, etc.) could be bottleneck for its domestication.

The objective of research is to evaluate the potential for domestication of nine MAP species with high market potential distributed in Latvian natural habitats: cowslip (*Primula veris*), woodruff (*Galium odoratum*), mezereon (*Daphne mezereum*), coltsfoot (*Tussilago farfara*), pasqueflower (*Pulsatilla pratensis*), lily of the valley (*Convallaria majalis*), ground-ivy (*Glechoma hederacea*), greater celandine (*Chaledonium majus*) and lady's mantle (*Alchemilla* spp). In 2019, seeds and/or plant parts were collected from 5 different wild populations of each species in different Latvian climate regions, to test their adaptation to commercial growing. Different factors (light, moisture, temperature etc.) were tested under controlled conditions to break natural dormancy of wild seeds. Collected populations were subjected to field trials under organic conditions. Different growing technologies were selected and used for each species, taking into account its biology (for example, shadowing, mulching, distance between plants etc.).

Important traits for agricultural practices such as growth habit, plant height, yield, etc. for each population were evaluated. Quality assessment of MAPs harvested both in the wild and in organic production system on the basis of their phytochemical composition was carried out. Obtained results showed, that there is future potential of Latvian local MAPs genetic resources for their direct or indirect (via breeding) introduction in commercial growing.

Decisions about potential of commercial growing for each specie and the most promising populations for domestication were taken only based on all data obtained.

Acknowledgments

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CHARACTERIZATION UNDER LOW N CONDITIONS OF ADVANCED BACKCROSSES OF EGGPLANT *(S. Melongena)* WITH INTROGRESSIONS FROM *S. Elaeagnifolium*

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Keywords: breeding, introgression lines, nitrogen use efficiency, wild relatives, yield

With the aim of introgressing traits related to tolerance to abiotic stresses in eggplant (*Solanum melongena*), we obtained hybrids and first backcrosses (BC1) between eggplant and the silverleaf nightshade (S. *elaeagnifolium*), an invasive weed highly tolerant to drought able to grow in marginal and nutrient-poor environments (García-Fortea et al., 2019). By means of marker-assisted selection using Single Primer Enrichment Technology (SPET) high-throughput markers (Barchi et al., 2019), successive backcrosses have been made for obtaining advanced backcrosses of *S. elaeagnifolium* with the recurrent *S. melongena* parent. A set of 56 genotyped plants from the BC2 and BC3 generations was evaluated together with the recurrent parent in an open field plot. The only N fertilization came from water used for the fertigation (0.66 mM N). Morphological, biomass, yield and fruit composition and biochemical traits were measured. N and carbon (C) contents were measured in both fruits and leaves and NUE was calculated. The genotyping results revealed that most of the genome of the wild *S. elaeagnifolium* was represented in the BC2 and BC3 generations. A wide variation, compared to the one observed in the recurrent parent, was found among the BC2 and BC3 segregating generations for the traits evaluated. Interestingly, transgressive plants were found for yield traits, with some plants having much higher yield and NUE than the recurrent parent. In this way, the eggplant recurrent parent had an average yield of 2.9 kg/plant, with a standard deviation (SD) of 0.9 kg/plant, while the advanced BC2 and BC3 backcrosses had a mean of 2.0 kg/plant and a SD of 1.7 kg/plant, with a maximum value registered of 8.1 kg/plant. The wide variation observed in the advanced backcrosses indicates that lines with better performance under low N fertilization than the recurrent parent may be selected. The phenotype-genotype association analysis allowed the identification of 13 putative QTLs for several of the traits measured. Some of the most relevant QTLs were a QTLs for plant height in chromosome 8, a QTL for stem

diameter and plant biomass in chromosome 4, a QTL for fruit weight in chromosome 7 and two QTLs for both yield and NUE in chromosomes 7 and 12. Overall, the results reveal that selection of eggplant lines carrying introgressions from *S. elaeagnifolium* may result in materials with improved performance under low N cultivation conditions, improving the sustainability of the crop.

Acknowledgements

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PRE-BREEDING OF WHITE LUPIN FOR ANTHRACNOSE TOLERANCE

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Keywords: resistance breeding, *Colletotrichum lupini*, *Lupinus albus*, CCP

White lupin (*Lupinus albus* L.) renders protein-rich seeds of high quality and is a good alternative to soybean, especially in the temperate zone with cool spring temperatures. It offers many highly interesting ecosystem services such as nitrogen fixation, deep rooting, active phosphorous acquisition and pollinator attraction, and it is tolerant to frost in early development stages as well as to summer drought during maturation (Lucas et al., 2015). Therefore, it is particularly interesting for organic and other sustainable farming systems. Today only 100 hectares of white lupins are grown in Switzerland because of its high susceptibility to anthracnose, a seed and rainsplash transmitted fungal disease caused by the pathogen *Colletotrichum lupini* (Talhinas et al., 2016). Infected plants show twisting and wilting symptoms and young pods are damaged by the pathogen, which in the worst case can lead to total yield loss. Seed hygiene and seed treatment can lower the primary inoculum, but without breeding for more tolerant cultivars, white lupin will not be able to be grown under Swiss conditions (Arncken and Messmer, 2018).

Since 2014 the FiBL plant breeding group has established pre-breeding in white lupin for anthracnose resistance. Each year, about 100 genetic resources, cultivars, landraces and breeding lines from all over the world have been evaluated and selected in the field under high disease pressure. Crosses have been made between tolerant genotypes and commercial cultivars, and offspring has been propagated in early generations under induced disease pressure in the field. In order to compare different breeding strategies, pedigree selection was started in segregating populations, and in parallel, a Composite Cross Population (CCP) originating in the first successful crossings was created and propagated over the years to enhance genetic diversity. Positive and negative mass selection were performed in the CCP.

In autumn 2020, we started to test the best F6 progenies with artificial inoculation under controlled conditions according to a newly developed protocol (Alkemade et al., in press).

A characterization of our present genepool concerning anthracnose tolerance will be given, including the CCP and the best F5/F6 breeding lines.

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RESPONSE OF DIFFERENT GENOTYPES OF *Brassica oleracea* var. *gongylodes* L. TO DROUGHT STRESS

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Keywords: *Brassicaceae*, gas exchange, chlorophyll a fluorescence, antioxidant activity

Drought is one of the main stresses facing agriculture in areas such as the Mediterranean, characterized by water scarcity. The lack of water is a great problem in this region, characterized by warm summers with little rainfall and, therefore, long periods of water unavailability, which leads to drought stress in plant species. Understanding the strategies implemented by plants to overcome this abiotic stress could allow us to identify more sustainable solutions to face a problem that, probably in the future, due to global change, will be increasingly frequent.

Under the BRESOV project, *Breeding for Resilient, Efficient and Sustainable Organic Vegetable* production, one of the objectives of this project is to identify genotypes that are more tolerant to drought stress, which is very common in the Mediterranean area.

An important role in the response to drought stress is related to identify the genotypes resistant/tolerant to this stress for genetic improvement of *Brassica oleracea* crops.

In this context, the aim of this trial was to understand the effects of drought stress on some morpho-physiological parameters on three genotypes of kohlrabi (*Brassica oleracea* var. *gongylodes* L.). The experiment was conducted in 2018/2019 in greenhouse in an organic farming located in Santa Croce Camerina (36°51’13.3’’N, 94 m above the sea level), Sicily, Italy.

A genotype belong to the gene bank of the Crop Research Institute, Czech Republic (Libochovicka Bila Rana’), and two to the gene bank of the University of Warwick, UK (‘Domino Gs’, and ‘Azur Star Gs’) of kohlrabi were subjected to three water treatments. The trial was a randomized block design, which included three irrigation treatments: (1) a control (T1), fully irrigated (100% ETc); (2) moderate deficit irrigation (T2) irrigated to replenish 55% ETc (T2); (3) severe deficit irrigation (T3) irrigated to replenish 33% ETc. To evaluate the response of the different genotypes, morphological parameters (fresh and dry biomass, and characteristics of the leaf and enlarged stem), physiological parameters (content in chlorophyll, Relative Water Content, gas exchange and chlorophyll *a* fluorescence), polyphenol content, and antioxidant capacity were recorded.

The results obtained shown that ‘Azur Star Gs’ and ‘Libochovicka Bila Rana’ showed a better adaptability to drought stress conditions, demonstrating how the genetic pathway can be a valid tool to overcome the problems that occur due to the unavailability of water.

The monitoring of physiological parameters appears to be a useful tool both for the evaluation of genotypes and for the management of irrigation.

INTERCROPPING MAIZE AND COWPEA AS A SUSTAINABLE TECHNIQUE TO ADAPT THE PRODUCTION TO CLIMATE CHANGE IN PORTUGAL

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Keywords: *Vigna unguiculata, Zea mays*, grain yield, LER, soil management

Maize is an arable crop with greater expression in Portugal and can be found from North to South of the country. Cowpea is a grain legume cultivate worldwide due to adaptation to drought, nitrogen-fixing ability and high nutritional values. With climate change, average temperatures start to rise, the availability of water for irrigation is decreasing and it is necessary to think about less demanding crops at soil level. There are several local populations of cowpea (*Vigna unguiculata* (L.) Walp.) in Portugal which can be intercropped with maize with various potential benefits, however, there is little information on this intercrop in Portugal or in similar contexts. The aim of the current study was to evaluate Portuguese cowpea populations intercropped with maize for human consumption grown organically under different production conditions. Experiments were conducted in order to identify the best genotype combinations of cowpea and maize, to optimize the seed rate and the number of irrigations during the crop cycle. The field experiments took place over three years (2018 to 2020) in three locations in Portugal: Braga (North), Idanha-a-Nova (Center) and Elvas (Alentejo) each one with different edaphoclimatic conditions. During the first year, eleven genotypes of cowpea were characterized in order to find the three best, crossing the results of the locations. In the second year, the three populations of cowpea were intercropped with a Portuguese cultivar of maize, in two different sowing densities. In the third year of the trial, after choosing the most suitable sowing density of cowpea, two different irrigation levels were tested. The results obtained indicate that the factor "genotype" and "local" originated highly significant differences for all parameters evaluated. Both in 2018 and in 2019 the edaphoclimatic conditions of each location significantly influenced the duration of the vegetative and reproductive phase of the plants. Analyzing the index LER in Elvas and Idanha-a-Nova, some treatments showed values higher than 1, in contrast to what happened in Braga, which may indicate that the intercrop is more favorable in places where temperature are higher and there is low humidity in the soil.

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GENETIC MAPPING OF ANTHRACNOSE RESISTANCE IN WHITE LUPIN

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Keywords: *Lupinus albus*, *Colletotrichum lupini*, breeding, GWAS, phenotyping

White lupin (*Lupinus albus*) is a valuable grain legume with a high protein content and quality, contributing to soil fertility (Monteiro *et al*., 2014, Lambers et al., 2013). Its high yield potential could make it a sustainable alternative for imported soybean in Europe (Lucas *et al*., 2015). However, lupin anthracnose, caused by the air- and soil-borne fungus *Colletotrichum lupini* severely limits cultivation as low levels of seed infestation can already cause total yield loss (Talhinhas *et al*., 2016). Host resistance is crucial for managing anthracnose but a better insight into the genetic basis is required. We developed a high-throughput phenotyping tool that identifies field-relevant anthracnose resistance under controlled conditions. For inoculation, we identified a local, highly virulent C. *lupini* strain. Phylogenetic analyses revealed that the strain belongs to a globally dispersed genetic group corresponding to Dubrulle *et al*.'s (2020) C. *lupini* group II. Using the developed tool we phenotyped a diverse collection of 200 white lupin accessions, revealing a strong segregation between susceptible and resistant plants, potentially holding novel sources of resistance. Genotyping-by-sequencing was performed and the generated single-nucleotide polymorphic markers (SNPs) are currently being used for genetic mapping. Quantitative trait loci (QTLs) for anthracnose resistance will be presented aiding to improve and speed up white lupin breeding programs.

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SELECTION OF ADVANCED LINES FROM ONFARM- CONSERVED DURUM WHEAT LANDRACES FOR RAINFED CONDITION OF TURKEY

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Keywords: landraces, selection, durum wheat, rain-fed

The aim of this study was to select superior durum wheat lines in terms of quality parameters and grain yield among on farm conserved winter durum wheat landraces during the last three years. In the first year of the project, totally 185 different single spikes were selected based on spike and plant morphology from different farmer's field. Then, each single spike was planted together with semi-dwarf checks under rain-fed conditions of Central Anatolia to test winter hardiness, drought and yellow rust resistance and 33 head rows were selected based on phenotypic selection. In the third year, these lines were tested under augmented design together with two common checks. There were great variation among selected lines especially for grain quality parameters such as sds sedimentation from 17.0 to 35.0 ml, semolina color from 23.4 to 29.3, wet gluten from 30.6 % to 50.7%, and gluten index from 61.5 to 95.0. In addition to grain quality parameters, grain yield of these lines were also very comparable to semi-dwarf checks and they changed from 1.38 t/ha to 6.03 t/ha.

The selection project carried out during the last three years showed that the durum wheat landraces still have great potential to select superior genotypes in terms of both grain yield and quality especially for rain-fed conditions of Turkey.

UNTWIST – UNCOVER AND PROMOTE TOLERANCE TO TEMPERATURE AND WATER STRESS IN *Camelina sativa*

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Keywords: stress tolerance mechanism, heat, drought, systems biology, crop management, camelina

Climatic variability and extreme weather events are increasingly impacting crop yield and value. The EU-Horizon H2020 Project UNTWIST (No 862524) addresses this challenge and takes advantage of the climate-resilient, traditional European oilseed crop camelina to provide a mechanistic understanding of successful adaptation strategies to drought and heat stress. For this, the interdisciplinary UNTWIST consortium involving AIT Austrian Institute of Technology, Institut National de Recherche pour l'agriculture, l'alimentation et l'environnement (INRAE), Rothamsted Research (RRes), Forschungszentrum Jülich GmbH (FZJ), University of Bologna (UNIBO), Camelina Company (CCE), Iniciativas Innovadoras (INI), and RTDS Association (RTDS) investigates the multi-layered responses of a set of genetically diverse Camelina genotypes to drought and heat stress in an in-depth systems-based approach. Climatic, physiological and multi-omics data will be used to develop predictive models and robust markers for crop performance for variable environments. Moreover, new knowledge will be translated into crop improvement and optimized management strategies. UNTWIST´s long term aim is to improve crop resilience and yield stability in changing, challenging climates; its legacy will contribute towards increasing the sustainability of European agriculture.

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COMPARISON OF BIOCHEMICAL PROFILE AND ANTIOXIDANT CAPACITY AMONG TUNISIAN AND ITALIAN CULTIVARS OF CAULIFLOWER

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Keywords: *Brassica*, polyphenols, flavonoids, phenols, antioxidant potential

The species belonging to the family of *Brassicaceae* are commonly used for culinary, medicinal and industrial purposes. Many studies focused on the polyphenol content and the antioxidant capacity of those species nether less few were interested to the leaves of the cauliflower. Therefore, in this study we extracted and quantified the total polyphenols and flavonoids content. The analysis by HPLC DAD identified and quantified twelve phenolic compounds. Antioxidant activities were assessed by a DPPH scavenging assay. The biochemical data showed as well detailed content in vitamins, polyphenol and flavonoid compounds and antioxidant capacity (DPPH) for three Tunisian cultivars of cauliflower. The results were compared with Italian cultivars of cauliflower and cabbage from the same geographic origin. The biochemical composition and bioactive activity significantly vary in function of the crop (cabbage and cauliflower) and to the geographic origin of the plants (Tunisian and Italian). The Italian varieties, adapted to the warm Mediterranean climate, exhibit the highest content of both flavonoids (7.41 mg QE/g), total phenolic content (10.88mgEAG/g DW) and the most important antioxidant (41.28mg EAG/g) and the anticholinesterase activities (5.17%) comparing to those content as reported respectively in the Tunisian cultivars (6.48mg QE/g), (8.72EAG/g DW), (31.26mg EAG/g), (4.63%). In addition, the antioxidant capacity was correlated with the phenolic content. This study showed that the leaves of cauliflower, those neglected parts, can serve as important natural source of valuable nutrient or for pharmaceutical uses.

EXPLOITATION OF *B. Oleracea* COMPLEX SPECIES (N=9) FOR INCREASING THE RESISTANCE TO *Xanthomonas campestris* pv. *campestris* IN THE RELATED CROPS

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Keywords: breeding, Xcc, sustainable agriculture, *Brassicaceae*, organic production

Brassicaceae vegetables are considered a staple food in many areas all over the world; they are important for human nutrition mostly for nutraceutical and antioxidant traits and for industrial process.

Several diseases affected *Brassica* species, mostly the commercial cultivars, and black rot disease, caused by *Xanthomonas campestris pv. campestris* (Xcc), is one of the most destructive. This phytopathogenic bacterium has several variants that constitute nine races, the most widespread in Europe are the races 1 and 4.

Seeds are the main source of infection and an effective means for transporting Xcc over long distances. Wind, aerosol, rain, insects, irrigation and other crop operations contribute to the formation of an epiphytic inoculum of the bacterium, which penetrates the plant through the hydathodes when the droplets of guttation are absorbed in the leaf. To evaluate the resistance to Brassica accession at Di3A we used two Xcc strains isolated in Italy and belonging to race 1 and 4.

Twenty-eight accessions from ten species were tested: *Brassica hylarionis, Brassica oleracea, Sinapis alba* spp. *alba, Brassica villosa, Brassica incana, Brassica drepanensis, Brassica macrocarpa, Brassica bourgeaui*. The inoculation was carried out favouring the bacterial penetration through wounds in order to ascertain the resistance thus excluding the influence of the hydathodes. The leaves were inoculated by wound in the secondary veins, utilizing mouse tooth forceps wrapped in cotton and immersed in the bacterial suspension (10^8 cfu ml^{-1}).

The symptoms were recorded from seven days post-inoculations using a five-point disease scale. The symptoms recorded at the first date very often coincided with small chlorotic or necrotic areas around the wound. When the symptoms did not progress over the time they were recorded as 0 (resistance). Symptoms evolved according to the inoculated species with black vein in areas adjacent to the inoculation point surrounded by chlorotic areas. In later stages the leaves of the most susceptible species wilted.

The results showed that two accessions of *Sinapis alba* spp. *alba* were resistant when inoculated with both races, while a third showed a slight susceptibility. The other species of the genus *Brassica* were susceptible to the bacterium. The accessions of *B. oleracea*, as reported in the literature, showed a variable susceptibility with differences related to the *varietas* and the accession. The accessions of *B. oleracea* var. *acephala* were less susceptible.

BEHAVIOR OF A WHEAT LANDRACES COLLECTION FROM BASQUE COUNTRY FACE TO BUNT INFECTION *(Tilletia caries)* IN ORGANIC FIELD TRIALS

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Keywords: organic production, germplasm

Wheat landraces are an important source of genetic variability for agronomic traits, as resistance to biotic stresses or adaptability and of great importance in low-input agriculture (Giraldo *et al*., 2010). Moreover, they can be essentials in the creation of new germplasm as the new Organic Heterogeneous Materials (OHM) that will be allowed in the new rules of European organic production from 2022 (Anonymous, 2018). For more than 10 years, local landraces of wheat have aroused the greatest interest among organic producers of arable crops in the North of Spain, and particularly in the Basque Country due to their characteristics for making bread in small, local bakeries of great quality. The main issue for organic farmers that produce these local landraces has been the bunt infection, which has meant the loss of lots of self-produced grain for multiplication. This situation can mean the loss of this valuated germplasm by farmers.

A collection of 23 genotypes of local landraces of wheat from the Basque Country provided by the Plant Genetic Resources Centre (CRF) and conserved in the NEIKER Germplasm Bank, and 2 check varieties, were tested on an organic certified field of NEIKER located in Arkaute (Álava – Basque Country – Spain) in a three-year trial, evaluating their behavior against bunt infection (*Tilletia caries*) in the presence of different seed treatments allowed for organic production. The objective of the trial was to evaluate the performance of the seed treatments, but it was observed a differential behavior between different landraces, which indicates the presence of different resistance capacities against infection by bunt.

The results of these field trials and the response of the different landraces to bunt infection will be presented.

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ON-FARM TESTING OF EMMER AND EINKORN LANDRACES UNDER ORGANIC CONDITIONS IN HUNGARY AND THE SLOVAKIAN UPLAND

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Keywords: einkorn, emmer, landraces, organic, value chain

The widespread cultivation of a few species has led to a decreased nutritive value of food and feed and an increased vulnerability of production systems. Ancient small grain cereal species seem to be good alternatives to common wheat, especially in the form of heterogeneous landraces grown under marginal farming conditions. Ancient cereals, like emmer and einkorn are also good candidates to increase diversity in the field and in human diets, while mitigating climate challenges. In Hungary, currently only about 400 hectares are cultivated with einkorn and an even smaller area is used for producing emmer, while there is growing interest and demand from consumers. In order to enhance the availability of ancient cereal grains and products, and to promote the development of a value chain, built on emmer and einkorn cultivars, ÖMKi has initiated organic on-farm trials using hulled wheat landraces in 2018. Besides yield, disease resistance and quality traits were also determined. To provide sufficient raw material for interested farmers as well as for milling, baking and pasta making tests, seed propagation took also place under on-farm conditions.

In our on-farm tests, 9 emmer (7 winter and 2 spring) and 2 einkorn landraces together with registered varieties (2 emmer and 3 einkorn) were investigated. So far, the tests were performed in two consecutive years. All the accessions were tested on-station (Agricultural Institute CAR, Martonvásár) for comparison, under conventional semi-intensive circumstances, (60-60-60 kg) NPK fertilization was used before sowing, no herbicide or pesticide treatment was applied, weeding was carried out by mechanical harrowing), all accessions were sown in autumn. There were four and three on-farm testing sites in cropping years 2018/2019 and 2019/2020, respectively. Depending on the farmers' preferences and the sowing seed availability, not all of the cultivars were tested on all farms. Želiezovce organic farm hosted a wider range of accessions. The soil quality there was high, very rich in nutrients. The other locations (e.g. Nagykáta, Bugac) have poor or very poor soil type and are not suitable for common wheat production.

The results of the first two years show that under favourable conditions (e.g. in Želiezovce) einkorn and emmer can reach relatively high yields (between 2 to 4,5 t/ha), and some landraces even outperformed the registered varieties or were not statistically different from them. Under poor, extensive conditions (e.g. Nagykáta), emmer accession GT 1399 produced similar yield (2,5 t/ha) on-farm, as was experienced on-station. The low performance (< 1 t/ha) of emmer cultivars in Bugac can be explained with the extreme drought and the marginal sandy soil conditions at this location. In 2019, *Fusarium* was a significant problem in the country, however the organic on-farm emmer and einkorn accessions generally were much less affected than common wheat varieties. On one site (Füzesgyarmat), however, there were more severe field symptoms of *Fusarium* on the spikes of the three tested emmer wheat accessions. Nevertheless, on all sites, mycotoxins (DON and ZEA) were either not detectable or their levels were way below the limit set on kernels, even in the case of more severe spike infection, which is another advantage of hulled cereals. We recorded moderate fungal infections in Martonvásár, which may have resulted from the chemical fertilization. Although emmer cultivars show different sensitivity to fungal diseases (e.g. leaf rust, stem rust), most einkorn accessions proved to be completely resistant to leaf fungal diseases based on the present and previous results.

While both emmer and einkorn cultivars have a higher protein, flavonoid and lipid level, and antioxidant activity compared to common wheat, einkorn accessions show a higher level of bioactive components compared to emmer cultivars.

Although soil quality and agricultural techniques of each site played a major role in the performance of tested cultivars, emmer and einkorn landraces proved to be suitable alternatives for organic farmers for diversification, especially in case of marginal farming conditions.

PRODUCTIVITY OF SOYBEAN VARIETIES IN ORGANIC CULTIVATION PRACTICE IN LATVIA

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Keywords: soybeans, productivity, climatic conditions, organic

The aim of this study was to evaluate the productivity potential and suitability of soybean varieties created in Europe for cultivation in Latvian agroclimatic conditions, applying organic cultivation practices. The research was conducted in 2018 and 2019 at the Institute of Agricultural Resources and Economics Stende Research Centre (57˚11'20''N, 22˚33'43''E). The study includes 15 soybean varieties from breeding companies in various European countries with environmental conditions similar to those of the Baltic region. All varieties correspond belong to the early maturity class 000 and 0000 on the advice of breeders. The experiment was arranged in 10 m^2 plots in 4 replicates, with sowing rate 60 germinating seeds per 1 m^2, no additional fertilizer was used, pre-crop barley, weed control - mechanical. The seeds were treated with Rhizobium bacterial product HiStick® before sowing. The soil characteristics of the test field: clay sand structure, organic matter – 2.1-2.2%, pH 5.6 – 5.8, K2O – 106 – 197 mg kg-1, P2O5 – 128 – 172 mg kg-1.

In 2018 and 2019, the sum of active temperatures during the vegetation period was similar - close to 2000° C, however, in 2018 this amount was reached in 117 days, but in 2019 in 135 days. In 2018, the productivity of soybeans was adversely affected by the lack of precipitation (the amount of precipitation for the later soybean varieties during the growing season reaches only 157 mm). In 2019, the development of soybeans was limited by temperatures, which in several periods of soybean development were significantly lower than the norm (especially during germination and flowering).

In order to characterize the productivity of soybean varieties in this condition, the following indicators should be evaluated: number of productive plants per 1 m^2, the inventory was performed in eight places (0.125 m^2) in each study variant; the number of seeds in each pod, the total number of pods, the height of the first node from the ground, the mass of 1000 seeds, evaluating up to 40 plants in each variant. From the obtained data the productivity of one plant and the soybean yield from 1 m^2 were calculated.

Plant density per 1 m^2 is of great importance in assessing soybean field productivity. The germination of soybeans in the field is significantly affected by meteorological conditions. The results of the study show that according to this indicator, there were large differences between soybean varieties, especially in 2019, when the germination period had lower temperatures. The average plant density in 2018 was 42.5 plants per 1m^2 or 70% of the sowing rate, but in 2019 – 13.9 plants per m^2 or 23% of the sowing rate. In both years, the highest germination in the field condition was determined for the varieties 'Merlin', 'Alexa' and 'Maja'.

Comparing the varieties according to the average number of pods per plant, significant differences were also observed by years: 12.49 ($LDS_{0.05}$= 5.15 pods per plant) in 2018 and 34.51 pods per plant ($LDS_{0.05}$=10.88 pods per plant) in 2019. In addition, in 2019 a moderately close and significant correlation was found between the number of pods per plant and plant density r = 0.558 ($LDS_{0.05}$ = 0.514, n=15). The largest number of pods from the plant was found for the soybean variety 'Viola' - 45.25 ± 18.33 pods at density 18.75 plants per m^2 in 2019, and 15.43 ± 4.69 pods at density 43 plants per m^2 in 2018.

The number of seeds in the pod is a relatively stable indicator. Over the years the average number of seeds was 1.84 in 2018 and 1.93 in 2019. In both years, a relatively large number of seeds in the pod were found for 'Alexa' (average 2.06 ± 0.21 and 2.15 ± 0.22 seeds in the pod) and 'Viola' (average 1.95 ± 024 and 2.26 ± 0.28 seeds in the pod).

Comparing soybean varieties by seed weight, the higher 1000 seeds weight was obtained in 2019 (average 180.58 g, and 165.37 g in 2018). In both years this indicator was relatively high for the variety 'Maja' (168.82 ± 3.94 g in 2018 and 212.15 ± 3.00 in 2019) and 'Paradis' (184.33 ± 5.54 g in 2018, 209.81 ± 6.82 in 2019).

The productivity of one plant was calculated taking into account the number of seeds collected from the plant and the weight of 1000 seeds. The plant productivity was significantly higher in 2019 - on average 11.97 g per plant (3.77 g - in 2018). Soybean varieties with the highest number of pods had higher plant productivity (correlation coefficient r_{2018} = 0.821 and r_{2019} = 0.944). Plant productivity is also significantly and positively affected by the number of seeds in the pod (r_{2018} = 0.576 and r_{2019} = 0628), but negatively - by plant density per m^2 (r_{2019} = -0.571). In 2018, the highest plant productivity was calculated for varieties 'Abelina', 'Viola, 'Lajma', 'Toutatis' and 'Paradis' (productivity > 4 g per plant), but in 2019, varieties 'Mavka', 'Tiguan', 'Violleta', 'Abelina' and 'Viola' (productivity >15 g per plant).

Comparing soybean varieties according to their yield from m^2, the factor that most affected the results was the plant density (r_{2018} = 0.626, r_{2019} = 835). According to the analyzed productivity indicators and plant density per m^2, the yield of varieties was calculated. The highest yields were determined for soybean varieties 'Viola', 'Alexa', 'Madlena', 'Merlin' and 'Toutatis' in 2018 and 'Alexa', 'Viola, 'Merlin', 'Maja' and 'Tiguan' (in both years the yield is more than 150 g m^{-2}). Using organic cultivation practices, soybean varieties 'Alexa' and 'Viola' showed the highest productivity, respectively 257 and 254 g m^{-2} in two years.

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EVALUATION OF 50 PORTUGUESE LANDRACES, OPEN-POLLINATED POPULATIONS AND COMPOSITES OF MAIZE *(Zea mays L.)* IN LOW INPUT ORGANIC SYSTEM VERSUS CONVENTIONAL IN PORTUGAL

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Keywords: maize, landraces, populations, organic farming, conventional farming, underutilized crop

The objective of this work is to recover underutilized populations of Portuguese maize germplasm with gastronomic potential.

Phenotypic evaluations using HUNTERS descriptor (Plant **H**eight, **U**niformity, **L**eaf angle, **T**assel, **E**ar placement, **R**oot and **S**talk lodging) (Mendes Moreira *et al*, 2017) and yield were conducted, using 50 populations (40 populations were collected in 1979 at Azores (Bettencourt and Gusmão, 1982) and multiplied in 2018 and 2019 at ESAC; 7 populations from the Participatory Plant Breeding Program “VASO” in Sousa Valley, Portugal and 3 composites).

The trials followed the randomized complete block design with three replications in 2 locations in Coimbra. The two locations distance 1.3 km and intended to compare two agriculture systems: the low input organic agriculture (Caldeirão) and conventional agriculture. Data treatments followed ANOVA.

The genotypes ranged from 57 to 75 days-to-anthesis. Organic showed significant lower values for Plant Height, Uniformity, Leaf angle, Tassel, Ear placement and Yield. From the tested genotypes only three of them were in the top ten of both systems (Pg C0S0 19 - (Lousada 2019), 2499 and BulkAzores[1]). For organic we identify VA C0S0 19 - (Regadio Lousada) (4314 kg/ha), 2501 (4249 kg/ha) and BulkAzores[2] (4145 kg/ha) with the higher yield.

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Breeding for diversity

LIVESEED: ENHANCING RESILIENCE AT SYSTEMS LEVEL THROUGH BREEDING FOR DIVERSE CROPPING SYSTEMS

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Keywords: crop resilience, breeding strategies, diversity, systems-based approaches

One of the ways to improve crop resilience in organic agriculture is through increasing diversity. This can be done at crop level (through more diverse cultivars, cultivar mixtures and heterogeneous material) field level (through various types of mixtures of annual and perennial crops) and systems level (by increasing crop number and complexity of its relationships, such as done in agroforestry systems). The aim of LIVESEED Task 3.2 is to develop and optimize breeding designs and selection tools facilitating more diverse and resilient cropping systems of annual and perennial crops including agroforestry. Based on a better scientific understanding of the biological basis of crop resilience new breeding tools can be delivered, which can help accelerate the development and adoption of new cultivars (including multi-genotypes, multi-crop cultivars and improved germplasm at farm level). Next to a better understanding of crop phenology and morphology, interactions with the agroecosystem (e.g. plant-microbiome and weed competition), production / economic yield and product quality (e.g. nutritional, organoleptic, taste cultural values), also the involvement of the wider food system through multi-actor and participatory approaches is an important element of the conducted work. As a broader framework of analysis, the systems-based breeding approach is used (Lammerts van Bueren et al. 2018). With all involved partners the details of a common overarching approach of analysis was developed over four meetings from 18th September 2020 to 21st January 2021. A comparative approach is used, within and between case studies for the following aspects:

- Variety mixtures, populations with pure stand
- Crop mixtures and complex systems (e.g. agrofoestry)
- Sharing experiences with multi-actor approaches

The outcomes of these analyses will help to develop practical guidelines for breeding for more diversity:

- Screening germplasm for its performance in complex systems
- Search for best combinations

- Increase diversity level and performance
- Improvement of various strategies for weed competition
- Improve disease tolerance and resistance
- Comparisons of breeding strategies: strengths and weaknesses
- Methods for involvement of the value chain: multi-actor approaches

A number of guiding questions were used for a common analysis:

- Are there similarities / differences between the case studies?
- What types of similarities / differences are observed between the case studies?
- What is their nature: crop, region, climate, soil, farming system, or a combination of various factors?

The aim of the conducted work is not to develop a single approach but to develop guidelines for breeders and farmers to develop tailor made approaches adapted to the specificities of the crop, agro-ecological context, climate conditions and socio-economic and cultural contexts. In this way improved crop resilience can be achieved through tailor made approaches. Diversity in breeding approaches and methods can also help maintain agrobiodiversity and make agriculture more climate robust.

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WHY IS IT SO DIFFICULT TO BREED FOR SUSTAINABLE ORGANIC FOOD SYSTEM? SOME EXAMPLES ON CEREALS

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Keywords: ecobreeding, GxE interactions, participatory plant breeding, organic agriculture, ecosystem services

Thanks to a huge demand for organic food products, organic sector comes out of its niche and attracts a “massive” arrival of actors from the conventional sector. Concerning the seed sector, this phenomenon contributes to copying the current model by simply substituting conventional field trial networks by organic ones. And the targeted traits are also, most of the time, those commonly selected in the conventional sector (i.e. yield, quality, disease resistance, climate tolerance, nutrient efficiency, etc).

In this paper and based on action research results, a geneticist and a sociologist question the difficulty of thinking about a new disruptive approach to plant breeding for organic food system, closer to the main values carried by the organic sector in its plurality.

What is an organic food system? How to approach its plurality?

Following the FAO definition, a food system encompasses all the stages: growing, harvesting, packing, processing, marketing, consuming and disposing of food. Organic food system is not monolithic, because a great diversity of situations may be found for each of these stages. Some actors strictly respect the ban on synthetic chemical inputs while others are working on a complete redesign of a new alternative food system. Moreover, food system stages are interdependent, and rooted in social organizations and regulations that contribute to shape the practices and to increase their diversity.

Einkorn (*triticum monococcum*) represents an interesting case of study. In the industrial organic bakery sector, this cereal is considered as unsuitable for breadmaking due to its sticky dough and inadequate rheological properties and is either not considered, either usually mixes with wheat flour. Organic long marketing channels request productive varieties, adapted to industrial processes; whereas artisanal and short chain sector working with their consumers privilege tasty, healthy and local varieties. Their minimal processing using very slow kneading speed, optimal hydration of the dough, local sourdough, allows producing pure einkorn breads, without the need to mix it with wheat flour.

How and what to breed for organic food system ?

Plant breeding is about finding the genotype G that best matches the target environment E. Breeders often think that the famous model $Y_{ijk} = G_i + E_j + (GxE)_{ij} + \varepsilon(_{ijk})$ remains the same when breeding for organic agriculture. They just change the E conventional by an E organic. This E is already complex because resulting from the combination of a biophysical environment (soil, climate) (BE) and a cropping management (M).

But breeding for organic food systems imposes to consider the huge diversity not only of organic management but also of organic food process/cook (P), marketing Channels (Ch), Social organisations (S) and Regulations (R). Therefore in the model, GxE should become GxBExMxPxChxSxR. These interactions should be assessed and optimized to promote organic-adapted genotypes G. What are such genotypes? G that must not be considered as simply undergoing or suffering from their environment - by having to adapt, resist, tolerate- , but should also be considered as impacting, modifying their environment by providing diverse services. Among them, we may list ***agro-ecological services*** (auxiliaries insects attractors, mycorrhization, soil depollution, nutrient supply, etc), ***process and marketing services*** (new healthy food products, new recipes, new markets, etc), ***socio-economic services*** (empowerment of actors involved in plant breeding, contribution to local economy and to living territories), ***regulatory services*** (participatory guarantee systems, change in the regulation), Consequently the Y of the model is no more the simple yield or a quality or a resistance but it has to encompass agro-techno-marketo-socio-regul-ecosystem services (ES) and others benefits (B) at a certain costs (C) from field to territorial level.

Organic data on ES+B+C=GxBExMxPxChxSxR are not dedicated to statistically compare the same genotypes in different M and BE, as it is usually done in plant breeding, but should aim to capture the diversity of services (ES) and of other benefits (B) provided by specific organic GxE combinations, at certain costs (C).

Conclusion : Taking plant breeding out of the domain of genetics and agronomy alone and leading it towards the sciences of ecology and human sciences is the real challenge of plant breeding for sustainable organic food system.

Thus contributing to advances in the field of social-ecological systems analysis, it seems urgent to combine work on GxE with work on biodiversity governance and on socio-technical construction of markets through networks, social values and technologies. This can be summarized by the concept of “participatory plant Ecobreeding”.

PARTICIPATORY ON-FARM BREEDING FOR DIVERSE AND ADAPTED WHEAT MIXTURES

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Keywords: participatory plant breeding, wheat, mixtures

Participatory plant breeding (PPB) is recognized as a way for farmers to obtain varieties better suited to their environments, practices and needs, especially in the context of organic or low-input conditions (Dawson et al. 2008). It allows to conserve and manage crop genetic diversity since a large number of often heterogeneous populations varieties is selected in different farms under contrasted conditions. Since 2006, researchers from INRA, farmers and facilitators of local farmers collectives from the Réseau Semences Paysannes (RSP) are working in collaboration in a wheat PPB project (Rivière et al. 2013).

A common feature sought by farmers for their varieties is heterogeneity because it allows them a more stable and more resilient production, and mixing varieties or populations is a practice increasingly used by farmers. However, many questions remain as how to efficiently select for adapted mixtures. A three year experiment has been carried out by several farmers and the research team within the PPB project to study the impact of different management practices on the behavior of mixtures.

Two main hypotheses were considered: (i) mass selection within pure stand populations allows a positive response in subsequent generations so it might be efficient to select within components before mixing, (ii) we cannot predict the behavior of a plant in mixture from its behavior as pure stand since new interactions between plants from different populations appear and modify their phenotypes and performances, so it might be more efficient to select within mixture plants that behave well in interaction.

Several practices were evaluated: (i) two years of mass selection within components before mixing, (ii) one year of mass selection within components, mixing those selections and then one year of mass selection within this new mixture, and (iii) two years of mass selection within the mixture. These practices were compared with the same mixture let to evolve without mass selection. Agronomic and morphological variables were measured on plants, spikes and grains.

First, the mixtures designed by the farmers were compared with their components. A positive mixing effect was found with most mixtures providing larger values than their components' means for many variables such as spike weight and length, and plant height. Then farmers' mass selection within components or within mixtures was assessed. In general, farmers selected mainly heavier spikes with more grains and in a lesser extent spikes with larger seeds. Selecting within mixtures gave larger responses but led to less diversified mixtures than mixing selections done within components. Overall, there was a significant added value of farmers' selection of mixtures compared to reproducing mixtures without selection.

These results will contribute to improving methods and tools for on-farm PPB not only for this particular group of farmers but also for any farmer's organizations who want to reintroduce within-field genetic diversity and become more autonomous in their agroecological systems.

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COMPARING TWO SELECTION STRATEGIES OF BREAD WHEAT DIVERSIFIED POPULATIONS ADAPTED TO ORGANIC FARMING

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Keywords: soft wheat, CCP, Dynamic Population, diversity

Organic farming systems are based on the adaptation to the social and pedoclimatic contexts in which they are implemented. Consequently, diversity (intra and inter varietal) is a crucial aspect of those systems, as it provides a greater stability and resistance to biotic and abiotic stresses (van Frank et al., 2020).

For several years, farmers in France have worked on strengthening diversity of farm varieties to better adapt them to organic farming. To do so, they use mass selection, mixtures (which evolve by open pollination and are called dynamic populations) or manual crossings. Which of these selection strategies has the best breeding potential?

In order to explore this question, two experimental bread wheat populations have been designed in 2013 from the same 6 parents (landraces): the first one is a dynamic population, created by mixing seeds from 6 parent varieties, and the second one, the Composite Cross Population (CCP), was obtained by manually crossing all the parents together (two by two, each parent being once male and once female). The two populations are cultivated in two places since 2015 and are evaluated each year for phenotypical characteristics and level of diversity.

The objective of the study is to explore the influence of three main factors on the agronomical behaviour of the two different populations and their level of diversity: the impact of the location, of the breeding strategy, and of human selection.

Our hypotheses are that the level of intra-population diversity of CCPs is higher than the one the dynamic populations, that the location influences the behaviour and level of diversity of the populations and finally that human selection tends to homogenise the populations.

The recent results show that human selection is the factor that has more impact on the populations (more traits or characteristics have changed for the different populations submitted to this factor), then comes the location. The breeding strategy does not seem to have an impact on the diversity or on the agronomical behaviour in our experiment.

An interesting result is also that human selection does not seem to homogenise the populations: the level of diversity is preserved compared to naturally selected populations. However, it can change the "shape" of the population, meaning that the agronomical performances of the population can be enhanced with human selection, without decreasing the diversity.

Those results need to be confirmed over the years.

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ASSESSMENT OF SPRING BARLEY VARIETY MIXTURES AND POPULATIONS IN COMPARISON TO HOMOGENEOUS VARIETIES

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Keywords: variety mixtures, populations, yield stability, leaf diseases, competitive ability against weeds

In the last decades the necessity to increase genetic diversity of plants within a variety has been widely discussed. Heterogeneous populations and variety mixtures are two ways to increase genetic diversity in varieties of self-pollinating cereals. The aim of the research was to find out the efficiency of spring barley (*Hordeum vulgare* L.) genotype mixtures and populations in improving certain traits: yield and yield stability, competitive ability against weeds and infection severity with leaf diseases.

Field trials were established during 2015–2018 under organic (O) and conventional (C) farming systems at two distinct locations in Latvia (Priekuli and Stende). The trials included two, three and five component mixtures (n=8) of barley varieties and breeding lines, mixture components in pure stand (n=16), three types of barley populations: simple (n=4) (cross of two parents), complex (n=5) (three to four parents crossed step by step) and composite cross populations (n=2) (CCPs), as well as homogeneous check varieties (n=3) currently grown in organic farming in Latvia – 'Abava', 'Rasa' and 'Rubiola'.

Data from all experimental sites (n = 14 (O = 7; C = 7)) were used to assess yield and yield stability. As measures of yield stability coefficient of regression and mean yield over environments according to Eberhart and Russell (1966), as well as ranking according to Fox et al. (1990) were used. The infection with foliar diseases – powdery mildew caused by *Blumeria graminis* and net blotch caused by *Pyrenophora teres* – was scored at location Priekuli under O (n=4) and C (n=4) conditions under natural infection background from 0 to 9, where 0 – no visible symptoms of disease, 9 – no green tissues of plants observed. To evaluate competitive ability against weeds, in Priekuli under O conditions (n=4), the visual assessment of crop ground cover at two barley development stages (GS 25–29, GS 29–31) and the visual assessment of weed ground cover at three barley development stages (GS 31–39, GS 59–65, GS 87–92) was carried out. Mixing effect for mixtures according to Kiær et al., (2012) was calculated and will be reported in the presentation.

Yield and yield stability. In general, the yield of the studied mixtures under both farming systems was similar to the average yield of the respective components grown in pure stand and check varieties. The yield of the mixtures was significantly higher just in some cases. According to adaptability to the environment and yield stability, the studied mixtures fitted into three groups: adaptability to higher yielding (conventional) conditions (n=4), good yield stability over environments meaning wide adaptability (n=3) and adaptability to lower yielding environments (n=1). Over the environments the average yield for all mixtures was higher than the average of the experiment; however, one of the eight mixtures exceeded it significantly. Yield of populations in comparison to check varieties varied, in some cases the populations had a significantly higher yield, but this was found in comparison with only one or rarely two check, as well as in one particular site. Only for composite cross population 'Mirga' a trend to out-yield all check varieties under O growing conditions in Priekuli, as well as wide adaptability and yield level above the average of the experiment, was observed.

Foliar diseases. Three of the eight mixtures had insignificantly lower severity of net blotch in comparison with the average of the respective components. For all mixtures and most of populations a significantly lower severity of net blotch in comparison with the most susceptible variety 'Abava', and in most cases insignificantly lower than that of the two other check varieties was observed. Powdery mildew severity of all mixtures was insignificantly lower than the average of the respective components and the checks. Infection of one simple population was significantly higher than that of all check varieties, but varied for other populations, not indicating that some of the populations would be superior according to the resistance against powdery mildew.

Crop ground cover and competitive ability against weeds. Comparing weed suppression ability of mixtures with average of the respective components and check varieties, no indications of better performance were found. The populations had worse (or similar) competitive ability against weeds than homogeneous varieties. Crop ground cover for both mixtures and populations was insignificantly lower than that for variety with the comparatively best ground cover 'Abava' and similar to that of the other two checks.

To summarise, in comparison to homogeneous varieties some advantages for mixtures and populations were found in respect to yield, yield stability and net blotch severity.

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BREEDING FOR WHEAT-PEA MIXTURES: ARE THE TRAITS OF PEA VARIETIES IN SOLE CROP PREDICTIVE OF THEIR BEHAVIOR IN MIXTURE?

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Keywords: intercropping, grain legumes, genotype x management interaction, cultivar selection

In France, the production of grain legumes has declined significantly over the past 20 years. Two of the main technical issues in pea cropping are the instability of yields, linked to the effects of abiotic and biotic stresses, and the high lodging rate at harvesting. An alternative to overcome these limiting factors is to grow peas in mixture with a cereal to better control canopy lodging, diseases and pests, and generate additional income. This is a widespread practice in Organic Farming.

One emerging issue is whether the choice of the pea cultivar that would be best suited to be mixed with the cereal should be based on identified varietal traits, already assessed in sole crop. We therefore explored to what extent the traits and performances evaluated in sole crop are predictive of those observed in mixtures? We compared pea varieties in sole crop and in mixture with bread winter wheat, for traits likely to ensure the success of the mixture, including phenology (such as beginning and end of flowering dates), morphology (such as pea height in the canopy at the beginning, at the end of flowering, and at the end of the cycle), and finally productivity (such as thousand grains weight and grain yield). Six trials were carried out in Organic Farming (*) or very low input (**) systems during the 2015/2016 to 2018/2019 seasons, in the Parisian Basin (Orsonville**), the north-west (Rennes*) and the center (Civray**) of France. Five to nine winter pea cultivars with contrasting phenological, morphological and productivity traits were sown as sole crop and mixed (at 75% of the sole crop doses) on the row with a single bread winter wheat cultivar.

In our environmental conditions:

- The dates of beginning and end of flowering, and the thousand grain weights of pea cultivars were very similar in mixture and in sole crop. The values of these traits in sole crop therefore seem to be predictive of those in mixture.
- All pea varieties were higher in mixture than in sole crop, whatever the developmental stage, confirming the ongoing tutor effect of wheat on pea.
- The pea variety heights at the start and end of flowering in sole crop seem to be predictive of those observed in mixture.
- Both for pea varieties height at the end of the cycle and for pea varieties grain yield, the values in sole crop did not seem to be predictive of those observed in mixture. Consequently, the development of specific breeding schemes and ratings for the evaluation of these traits in mixture appears necessary.

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EVOLUTIONARY PARTICIPATORY TOMATO BREEDING IN ITALY FOR ORGANIC AGRICULTURE

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Keywords: organic heterogenous material, participatory plant breeding, climate change

Cultivars specifically adapted to organic agriculture are lacking. Evolutionary breeding exploits the ability of Organic Heterogenous Material (OHM) to adapt to different pedoclimatic conditions and organic conditions.

The objective of this experiment was to test the level of specific adaptation of a population of beef-heart tomato to four organic farms, following two cycles of both natural and artificial selection in a program of evolutionary-participatory plant breeding (Ceccarelli and Grando 2019).

A beef-heart tomato population was created by crossing four local varieties selected for their suitability to organic conditions in France, Spain and Italy during the SOLIBAM FP7 project.

In 2018, 400 seeds of the F_4 generation were distributed to 3 organic farms in Sestola (Emilia Romagna), Campobasso (Molise), Castronuovo S.A. (Basilicata) and one research station (Rotonda, ALSIA, Basilicata). Participatory selection field days were held in each location before harvest time. Participants assigned a score (from 1 = poor to 4 = very good) to each of the 400 plants (Ceccarelli 2012). One berry was collected from the 20 plants with largest average score, as well as a second berry from each of all 400 plants. In each location, all the seed in each of the 400 berries was combined to generate a population derived from natural selection (NS), whilst 20 seeds were taken from each of the 20 best berries to generate a balanced farmers' selected population (FS). In 2019 the experiment was repeated, planting in each farm 400 plants of the NS population and 400 plants of the FS population. On the latter, a second selection cycle of participatory selection was conducted and seed was collected from the best 20 plants following the same procedure as the previous year. Similarly, one berry per plant was collected from the NS population.

In 2020 we tested the NS and FS populations from each of the four locations in all four locations. The 8 populations (4 NS and 4 FS) were evaluated in a randomized complete block design trial together with four local varieties chosen by farmers (LV) and two modern F1 hybrids chosen for their suitability to organic conditions as controls. Each of the 28 plots (14 entries x 2 replications) contained 20 plants, distributed in two rows, so that evaluators could better assess the plot in its entirety by walking between the two rows. Participatory evaluation field days were held and participants were asked to score each plot for: disease resistance, vigor, yield potential, uniformity and a final general score (Campanelli et al. 2015). In parallel, quantitative data on yield was being collected. For each plot, all berries up to the third truss were harvested as they ripened noting down the time of harvest. The berries were divided between marketable and non-marketable, each group counted and weighed.

Whilst data for this experiment is still being collected (at the time of writing tomato harvest is still ongoing), we can highlight some tangible results deriving from this experiment. Firstly, it was an opportunity to raise awareness and build self-confidence among local organic farming communities' members on the potential of evolutionary-participatory breeding (over 200 farmers took part to the selection over the three years); secondly this experience allowed to test in real-world conditions an experimental design and a participatory methodology, which could be easily replicated and out-scaled in other regions and for other crops, something of particular relevance in light of the perspectives offered by the new European organic farming regulation on OHM (2018/848/EU).

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SELECTING FORAGE LEGUMES FOR USE IN MIXTURE WITH GRASSES

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Keywords: alfalfa, grasses, mixed cropping, nursery, interaction

Due to positive interactions among grass and legume species, their cultivation in mixture offers higher forage yield potential compared to their monocultures (Nyfeler et al., 2009). Especially in organic agriculture where nitrogen fertilization is limited, grass-legume mixtures are, therefore, a valuable tool for ecological intensification. Interactions between genotypes within and among species seem to play a relevant role (Litrico, 2019). For example, Maamouri et al. (2017) found significant differences in the performance of some alfalfa (*Medicago sativa*) genotypes in pure stand vs. their performance in mixture with tall fescue (*Festuca arundinacea*). However, to the best of our knowledge, yet most breeding programs focus on selection in pure stands with few activities for performance in mixture going on. Many selection programs for forage crops include a spaced plant nursery where single plants are evaluated. Instead of growing these plants on bare soil, their cultivation in companion with the future partner would be straightforward to select genotypes well adapted for cultivation in mixture. In this study, we were growing spaced alfalfa plants of different accessions on bare soil as control treatment (CON), with undersowing of short growing lawn varieties of tall fescue and red fescue (*Festuca rubra*) (LAWN) and with undersowing of forage varieties of tall fescue and red fescue (FORA) to simulate increased competition/interaction with the companion grass. Thereby, our aims were to assess the extent of genotype-by-cultivation system interaction and to determine a suitable selection system.

At the site of Zürich-Reckenholz, Switzerland, 30 plants of 50 different accessions each (25 varieties, 25 landraces/ecotypes) were grown from 2017 to 2019 in the CON, LAWN and FORA cultivation systems, resulting in 4500 plants in total. For the CON treatment, an herbicide was applied following planting in a conventionally managed field to stop weeds growing in between alfalfa plants. In an organically managed field close by, lawn and forage varieties of tall fescue and red fescue were sown prior to planting of alfalfa plants for the LAWN and FORA treatments, respectively. Traits were recorded on a single plant basis before cutting (one cut in autumn 2017, four cuts in 2018, one cut in May 2019). Plant vigour was rated on a scale from 1 = good to 9 = bad. Diseases were rated upon occurrence from 1 = no symptoms to 9 = highly infected and included crown and root rot caused by *Sclerotinia trifoliorum* and downy mildew caused by *Peronospora trifoliorum*. Additional traits assessed visually were growth type (1 = erect, 9 = prostrate), stem diameter (1 = thin, 9 = thick), and leaf stem ratio

(1 = high leaf proportion, 9 = low leaf proportion). Analysis of variance (ANOVA) was done using the model

trait ~ cs + acc + cs:acc + e

where cs is the cultivation system, acc the accession, cs:acc the interaction between cultivation system and accession, and e the residual error. Correlations among the three cultivation systems were calculated as Pearson's correlation coefficient ($r_{FORA-LAWN}$, $r_{FORA-CON}$, $r_{LAWN-CON}$) based on means per accession and cultivation system (30 plants per mean value).

For all traits assessed, ANOVA revealed a significant to highly significant effect of cs (exception growth type during second growth of 2018 season) and acc. The cs:acc interaction was significant in all instances except for occurrence of downy mildew. As expected, the non-significant cs:acc interaction for downy mildew was also visible in the high correlations coefficients among all three cultivation systems ($r_{FORA-LAWN}$ = 0.86, $r_{FORA-CON}$ = 0.82, $r_{LAWN-CON}$ = 0.86). This may be explained by a homogenous disease pressure (spores coming from outside) and low interaction with the accompanying grasses. Contrary, correlations among cultivation systems for crown and root rot were low and not significant, what may be explained by a non-homogenous distribution of inoculum for this pathogen. Averaged over all cuts, the LAWN treatment was more predictive for the FORA treatment ($r_{FORA-LAWN}$ = 0.83) than the CON treatment ($r_{FORA-CON}$ = 0.77) for plant vigour, but the latter value still being relatively high. Despite the significant cs:acc interaction, similar plants could, therefore, be expected to be selected under the CON as under the FORA system regarding vigour. Differences among systems were more pronounced for growth type in the first cut, where $r_{FORA-CON}$ = 0.57 was relatively low, most likely due to strong grass culms forcing alfalfa plants to a more erect growth.

Despite significant cs:acc interactions, our results do not give a clear indication whether selection under the FORA system, which mimics the final field situation more realistically, would lead to different selection decisions than under the CON system. Growing offspring from experimental selections of the three cultivation systems in mixture and pure swards would be a next step to test efficiency of selection. Growing spaced alfalfa plants in companion with lawn grasses (LAWN) might be a compromise, as this system still allows an easy observation of plants and is in most instances more predictive for FORA than CON.

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WHICH MORPHOLOGICAL TYPES ARE NEEDED FOR ORGANIC MIXED CROPPING OF TRITICALE WITH WINTER PEA?

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Keywords: mixed cropping, winter pea, triticale

Under organic farming triticale is well known to be able to buffer the loss of peas during winter or disease attacks in spring and can help to avoid early lodging of peas and reduce lodging before harvest. The target of the mixture is high pea yield, whilst the yield of triticale should not be suppressed by peas too strong. In the “EU-Liveseed-project”, three different triticale varieties Agostino, Vuka and Securo were combined with ten different winter peas, differing in height and leaf type over two years. Short peas were suppressed and the total yield was best with tall peas. Best yield among winter pea was also reached with tall peas. It could not be shown that normal leaf type in winter pea can generally reduce triticale yield and increase pea yield. Lodging of tall peas started a little bit later with semi leafless types. Triticale varieties showed differences in suppressing winter pea. Related to early vigor, broadness of leaves, height and leaf diseases, which affect shadowing of peas, three triticale varieties were too few to find significant, principal effects. Additionally, a new trial was set up to test about 100 triticale, differing in many characters, in combination with winter pea Kolinda in 2019/20. Yield of both differed +/- 20% related to average of triticale and Kolinda. Results of these trials will be presented and discussed to develop the next steps in mixed cropping research.

ORGANIC BREEDING FOR DIVERSITY EXPLORING *Brassica* GERMPLASM – PORTUGUESE CASE STUDY

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Keywords: organic, genebank, *Brassica*

Awareness for agriculture sustainability and conservation is growing worldwide, proven by the increase in organic farming practices (in the form of farming area and wider range and amount of products grown). Alongside this, with the increased concern with climate changes, genebanks play a vital role by ensuring the safety of crops and supporting research. In Portugal, there's a small number of *Brassica rapa* and *B. napus* varieties which have been certified for organic agriculture, and, according to data from several European countries organic seed databases, it has been generally verified a low focus on these species, especially in the case of *B. napus* (European Commission., 2020). In order to highlight the value of the organic seed production and germplasm material, in this task we focused on obtaining and proposing new varieties of turnip and rapeseed crops, adapted to a sustainable and organic agriculture. Exploring the Brassica collection conserved at the Portuguese Genebank, 3 selection lines were chosen for *B. rapa* (SL1, SL2, and SL3) and 1 for *B. napus* (SL6). These lines were grown during three generations following organic farming guidelines. Mass selection criteria were applied to obtain a consistent and homogeneous seed bulk. The field trials took place in Braga, Portugal, in isolation conditions, and 150-200 plants per line were used in each selection cycle. It was possible to carry out the selection lines towards homogeneity and selected morphological (plant dimensions, type of leaves, leaf number) and reproductive (synchronized stages, seed harvest time, seed quantity) criteria. A proposal of 4 organic, homogeneous and consistent selection lines was obtained, each one with different characteristics and therefore purposes: SL1 being ideal to produce turnip greens; SL2 for turnip and turnip greens; SL3 for turnip; and SL6 for forage and biodiesel. In conclusion, genebanks and the conservation of plant genetic resources are an important asset to our society, by allowing the development and the enrichment of varieties that can aid in the response to the current times, where climate change plays an ever increasing challenge.

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NETWORK-BASED GWAS REVEALED SEVERAL CANDIDATES OF GENOMIC REGIONS ASSOCIATED WITH RASE-SPECIFIC RESISTANCES TO COMMON BUNT *(Tilletia caries)* IN WHEAT

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Keywords: *Tilletia caries*, resistance, wheat, GWAS, seedborne disease

In order to develop markers for Bt1, Bt2, Bt5, Bt7, Bt13, BtZ and Quebon-resistance against common bunt (*Tilletia caries*) in wheat, 455 wheat varieties and breeding lines were inoculated with 7 to 11 races of common bunt in field trials in 2018 and 2019, and resistance response was recorded.

Out of 455, 274 lines were selected and genotyped with a 25K SNP micro array chip (TraitGenetics, Germany). Network-based Genome Wide Association Analysis (GWAS) using a nonparanormal approach within Gaussian copula graphical model (semi-parametric) for reconstructing conditional independence networks were applied (Behrouzi and Wit, 2018.).

This method adjusts for the effect of all other SNPs and phenotypes while measuring the pairwise associations between them, and therefore accounting for population structure. The resulting genotype-phenotype network is a complex network made up of interactions among genetic markers and among phenotypes, and between genetic markers and phenotypes. Genetic maps of Allen et al. (2017) and Wang et al. (2014) have been used in order to map genomic regions for gene loci affecting the resistance to common bunt.

GWAS analysis revealed several candidate regions in association with at least two race-environment combinations. Based on the genetic map of Allen et al. (2017) at least 23 regions of interest have been identified: six on chromosome 2B, four on 1A, two on 2B 3B and 4A, respectively, as well as one region on 3A, 2D, 4B, 5A, 5B, 6B and 7B, respectively.

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SELECTION OF WINTER CEREALS FOR CEREAL-PEA MIXTURES TO IMPROVE BIODIVERSITY AND LER

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Keywords: intercrops, cereal breeding, wheat, triticale, LER

One of the most effective ways to enrich field biodiversity both above and below ground is the use of intercropping, a management system where two or more crops are grown together in the same season either as mixtures or as separated components in space and/or in time. As suitable varieties for mixtures can be seldom found, targeted selection approaches were started in Hungary within the frame of an EU H2020 project (REMIX).

Performance of selected wheat and triticale genotypes were examined in cereal-pea mixtures, which could be easily determined through Land Equivalent Ratio (LER= $(Ymix_1/Ypure_1)+(Ymix_2/Ypure_2)$) using grain yield values of the cereal (1) and the pea (2) components. Trials were set up in organic field using small plots (6 m^2/plot) with three replications arranged according to randomized complete block design. Mixtures were made of 50%:75% winter cereal – winter pea (pure stands: 450 wheat/triticale or 120 pea plants/m^2).

In order to find the right phenotypic ideotype, 8 contrasting (regarding earliness, plant height and thousand grain weight) winter wheat varieties and 4 winter pea varieties were examined in all combinations (32 mixtures). Based on the evaluation of two years data (2019-2020), no significant difference was found between the wheat-pea mixtures regarding LER (p=0.993) and wheat grain yield (p=0.981), but pea varieties yielded differently (p<0.001) in the mixtures ranging from 0.31 t/ha to 1.84 t/ha. Some differences in LER could be seen between the 4 groups formed according to the pea variety components. Mixtures made by the mixing of pea cultivars 'Aviron' and 'James' with the wheat varieties showed LER values between 1.2 and 1.5, while mixtures made of the pea variety 'Furious' had LER values between 1.4-1.7. The highest LER values were achieved with the mixtures of the pea variety 'Gangster' (mixtures with wheat varieties 'Mv Nemere' (LER=1.823), 'Mv Nádor' (LER=1.815) and 'Mv Ikva' (LER=1.755) were the best), but these values showed the highest variation (1.3<LER<1.8) as well.

In parallel, a cereal selection trial was started using one of the four pea varieties, named 'Aviron'. Nine winter wheat and nine winter triticale breeding lines originated from two selection methods (selection in cereal-pea intercrop system, selection for yield stability in monocrop systems) were analysed for grain yield grown in mixture. According to the results, pea intercrop showed negative effect on the grain yield of wheat ($p<0.001$) and triticale ($p=0.099$) lines, while significant difference between the two selection methods was only found regarding the grain yield ($p=0.01$) and LER ($p=0.025$) values of the triticale lines resulted therefrom. Breeding lines originated from selection for yield stability in monocrop system performed better than the others, except one wheat line. LER values of the 18 mixtures showed no significant difference having a range of 1.08-1.29 and 1.05-1.67 for wheat ($p=0.706$) and triticale ($p=0.482$), respectively. Average LER of the triticale-pea mixtures (LER=1.25) was higher than that of wheat-pea mixtures (LER=1.19). Considering the mixing ratio, a LER value above 1.25 would significantly increase the effectiveness of a management system, thus breeding lines over this value could be recommended for intercropping. One wheat and three triticale lines that had the highest LER value coupled with the lowest yield-drop due to intercropping were selected as promising materials for winter cereal-pea intercropping systems. These lines could be mixed with pea varieties which would increase LER the most. Based on our results, similarities in earliness and plant height of the cereal and pea components of the mixture are important (like mixing pea variety 'Gangster' with 'Mv Nádor' or 'Mv Nemere', which resulted in the highest LER values). Therefore, our selected short lines (1 triticale and 1 wheat) are recommended to be mixed with the pea variety 'Gangster', while the two taller triticale lines would have the highest performance as a mixture made with the tall pea variety 'Furious'.

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AGRONOMIC PERFORMANCE OF HETEROGENEOUS SPRING BARLEY POPULATIONS

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Keywords: composite cross population, yield stability, weed suppression ability, NUE, leaf and seed borne diseases

Heterogeneous populations of self-fertilizing crops can substantially improve the diversity within a single species fields and have the ability to evolve and adapt to particular environments while cultivated there for a number of seasons. Our aim was to test agronomic performance of spring barley (*Hordeum vulgare* L.) composite cross populations (CCPs) in order to identify their advantages and disadvantages in comparison to homogeneous varieties grown under organic farms in Latvia.

Seven covered barley and five hulless barley CCPs were compared to four covered check varieties Rubiola, Rasa, Abava (LV) and Anakin (DK) and one hulless check variety Irbe (LV) and seven mixtures of parental genotypes at three organic and one conventional farming sites in 2019 and 2020. Two of the populations were Danish origin (A.Borgen, Agrologica) and the rest were locally bred and cultivated under the respective farming system for 1-5 seasons before the start of experiment (F_4 - F_7 generation in 2019). The number of parents used varied between 10 and 32 including male sterile parents for three CCPs. Two of the organic sites were at the research institute at distinct locations (Priekuli and Stende) and the third site was in organic farm where the crop was grown with undersown red clover. The conventional site was research field with moderate input of agrochemicals (mineral fertilizer provided to obtain 5 t ha^{-1} yield, one application of herbicides, no fungicides). Yield stability was assessed over six environments by calculating coefficient of regression. To evaluate CCPs' weed suppression ability at organic farming sites at three barley development stages (GS 31-39, GS 59-65, GS 87-92) the visual assessment of weed ground cover was carried out. The weed suppression ability for each genotype was calculated as a difference between the weed ground cover in plots and maximum weed growth in plots without crop, expressed in percentage. Nitrogen use efficiency (NUE) defined here as the grain yield per unit of the soil N comprises both uptake (NUpE) and utilization efficiencies (NUtE). Harvest index (HI) were also calculated.The infection with foliar diseases powdery mildew caused by *Blumeria graminis* and net blotch caused by *Pyrenophora* teres was scored at location Priekuli, under natural infection background; for seed borne diseases (*Ustilago nuda* and *Ustilago hordei*) number of infected plants was counted.

The yield level in organic sites was comparatively low (2.86, 1.62 and 0.95 t ha^{-1} on average over the years), with the lowest at the farm site, and 4.60 t ha^{-1} at the conventional site with significant differences between all sites ($p<0.05$). All hulless barley entrees ranged below the covered ones according to the average yield over the sites. Four out of seven covered barley CCPs significantly surpassed the average yield over the experiment under organic environments and six of them ranked higher according to the average yield under organic environments in comparison to conventional environments. The most extreme ranking difference was found for CCP involving the highest number of parents and this difference was larger under the poorest yielding environments. Significant yield differences between populations and the respective mixtures were observed in six cases when population outyielded the mixture, but one mixture surpassed the yield of the respective population in three environments. Majority of CCPs yielded relatively stable over the eight environments, and three of them showed adaptability trend to unfavourable growing conditions, whereas three of the homogeneous varieties were the most adapted to higher yielding conventional environments.

The mean NUE values over three environments ranged from 38.0 to 72.6 g g^{-1} N. Two covered barley CCPs of Latvian origin and one CCP of Danish origin ranged in the top among investigated entrees according to the NUE values, showing also the highest values of HI (0.45-0.47). NUE value for six covered CCPs did not differ significantly if compared to the best performing variety Rubiola (65.7 g g^{-1} N). The variation in the NUpE and NUtE both contributed significantly to the NUE.

CCPs weed suppression ability differed as affected by the growing site and the year. In Priekuli covered barley CCPs performed better than the varieties in both years, while in Stende such trend was observed only in 2019. Hulless barley CCPs performed better than the check variety in Priekuli in 2019 and Stende in 2020. No differences between CCPs and varieties were observed at the farm site.

Majority of the CCPs were significantly less infected with net blotch than the average of the trial and below the infection of the varieties according to average AUDPC over three sites. In respect to powdery mildew severity, most of the CCPs ranged in between the most resistant and most susceptible varieties with Danish population being superior. The average number of plants infected with loose smut was the highest for Danish material (up to 1 plant m^{-2}) and all other CCPs ranged in between it and the most resistant varieties Rasa and Rubiola (0.02-0.04 plants m^{-2}). All Latvian hulless CCPs were found to be the most susceptible to covered smut with 1-6 infected plants m^{-2} on average.

In general, CCPs were found to be better adapted to growing under organic farming in comparison to conventional farming, with better ability to suppress weeds, with comparable NUE as homogeneous varieties. CCPs had advantages in respect to net blotch severity but possible high susceptibility to smuts.

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IDENTIFYING NITROGEN-EFFICIENT POTATO GENOTYPES FOR ORGANIC FARMING USING CANOPY DEVELOPMENT AND YIELD PARAMETRES

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Keywords: potato (*Solanum Tuberosum* L.), canopy, AUCCPC, nitrogen use efficiency, NUE

Potato (*Solanum Tuberosum* L.) production in Latvia is significant branch in agriculture, though in last five years potato production have slightly decreased.

Potato crop requires abundant nitrogen (N) to obtain high and qualitative tuber yield. Nitrogen management for potato is important from both a production and environmental standpoint. N deficiency can limit yield, while extensive N can leach to groundwater, creating pollution. According to Tiemens–Hulscher et al. (2014), in organic potato production N supply is much lower and often an important yield – limiting factor. The release of nitrogen from soil organic matter and from organic nutrient management sources is slow and highly depend on mineralization processes in the soil. Therefore, N management in organic farming is complicated and should be supported by varieties adapted to low and variable nitrogen availability to ensure yield stability.

Trial was carried out in organic field at the Institute of Agricultural Resources and Economics, Priekuļi, Latvia in 2020. We assed phenotypic variation among 20 potato genotypes in four replications, as well as green canopy cover and tuber yield. A plot size was 3.4 m² (16 plants). Genotypes were divided into three groups according to their maturity type (early, medium early and medium late).

During growing season, percentage of soil cover by the canopy was assessed for each individual plot twice a week, using digital photographs. A Canon PowerShot SX720 HS digital camera was connected and remote-controlled via smartphone. Photographs were processed using picture editor program to fix areas where image captured weeds, that caused an overestimation of ground cover. Object-based image analysis was conducted with “Canopeo” application.

In 2020, the spring was relatively cold. In May, when tubers were planted, the air temperature was 9.6 °C (2.2 °C less than long term data). Lower air temperature slowed down potato emergence until early June when air temperature increased (18.5 °C), with enough precipitation to ensure emergence and growth (99.3 mm, 122.3 % more than long term data). Plants emerged from 29 to 35 days after planting. Between late

June and July weather was cooler than usual (average air temperature 16.2 °C, 1.3 °C less than long term data) and rainfall level (133 mm) was particularly higher than long term data (by 154.7 %).

First late blight (*Phytophthora infestans* (Mont.)) damages on leaves were observed by the end of July. Early and medium early genotypes foliage was destroyed by 90 – 100 % in end of August while almost all medium late genotypes foliage remained green until haulm destruction.

The relationships between potato genotypes development of foliage canopy cover and tuber yield was detected according to first-year results. The Area Under Canopy Cover Progress Curve (AUCCPC) was assessed. We applied beta thermal days (Khan et al., 2013) instead of calendar time. AUCCPC showed significant impact ($p<0.05$) on tuber yield (t ha^{-1}). Analyzing data between genotypes yields (t ha^{-1}) and AUCCPC parameters, there is distinctly positive and significant correlation ($r=0.58$, $p<0.05$), especially for varieties 'Rigonda', 'Jogla', 'Magdalena' and 'Kuras', which might point to some nitrogen use efficient features similar, to what has been described by Ospina et al. (2014) and Tiemens–Hulscher et al. (2014). AUCCPC and yield correlation within genotypes in each maturity group was particularly positive and significant for medium early genotypes ($r=0.78$, $p<0.05$) and medium late genotypes ($r=0.70$, $p<0.05$), but not significant for early genotypes ($r=0.26$, $p<0.05$). This season tuber yield for early (29.2 t ha^{-1}) and medium late genotypes (27.6 t ha^{-1}) was significantly higher than for medium early genotypes (22.5 t ha^{-1}). Also, the percentage of large tubers (>50mm) in yield for medium early genotypes was significantly lower (16.8%) comparing to early genotypes (35.5%) and medium late genotypes (31.9%) having almost equal results of percentage of large tubers in yield. We didn't discover any statistical significance ($p>0.05$) between AUCCPC and percentage of large tubers in yield (>50 mm) during this season.

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EVALUATION OF WHEAT COMPOSITE CROSS POPULATIONS UNDER ORGANIC FARMING SYSTEM

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Keywords: spring wheat, winter wheat, composite cross populations, yield, quality

Wheat breeding for organic farming required to obtain genotypes which are able to be adapted to local conditions. Composite cross populations (CCPs) created by evolutionary breeding method increase resilience against environmental variations and climate change caused by global warming and offer an opportunity to produce populations that show small or no genotype-environment interaction (Brumlop et al. 2017). During three harvest seasons (2018, 2019 and 2020) field trials with four spring wheat (*Triticum aestivum* L.) CCPs: Convento C, Convento E from Germany (Dottenfelderhof), P1 (high gluten content) and P2 (resistant to common bunt) from Denmark (Agrologica), and three winter wheat CCPs: Popcorn (Denmark, Agrologica), Brandex, Liocharls (Germany, (Dottenfelderhof) and MV Elit (Hungary, Agricultural Institute of the Centre for Agricultural Research) were set up at location Stende under organic farming system. Randomised block design with four replications was applied; plot size was 10 m², seed rate 500 untreated germinable seeds per m². The main task of the study was to investigate agronomic traits (yield, grain quality, weed suppression ability (WSA) and resistance to the main diseases) of spring and winter wheat CCPs in comparison to the local spring wheat variety Uffo. The weed suppression ability for each genotype was calculated as a difference between the weed ground cover in plots and maximum growth of weed in plots without crop, expressed in percent (Hoad et al. 2008). Nutrient use efficiency was measured as well and will be reported in the presentation. The infection with foliar diseases yellow rust (*Puccinia striiformis*), brown rust (*Puccinia recondita*) powdery mildew (*Blumeria graminis*) and tan spot Pyrenophora *tritici-repentis* was visually scored under natural infection background. Winter hardiness of winter wheat genotypes was evaluated after renewing of the plant vegetation in scores from 1 to 9, were 1 - low. The obtained data was processed by using analysis of variance. Meteorological conditions during the investigation differed between the years. In 2018 the drought stress had a significantly negative impact on the plant development. During vegetation periods of 2019 and 2020, the temperature deviations and precipitation were close to the long-term norm. Meteorological conditions during vegetation periods 2018-2020 were not very suitable for progression of very high level of leaf diseases and significant yield losses were not caused.

No significant differences ($p<0.05$) between ***spring wheat*** CCPs average yield during the three harvest seasons were observed. The best results 2.47 t ha^{-1} showed population Convento C from Germany. Spring wheat CCP P1 from Denmark showed the highest grain quality with average protein content over the year's 14.38 mg kg^{-1}, gluten content 286 mg kg^{-1}, and Zeleny index 54.6. Spring wheat populations showed different weed suppression ability, ranging from 13 to 50%, with highest values for CCP 2 from Denmark.

Winter hardiness of ***winter wheat*** in 2018/2019 was satisfactorily (3 - 5 points) except for CCP Liocharls (1 point). In 2019/2020 over-wintering of all genotypes was good (5 - 9 points). Significantly higher average yield ($p<0.05$) 4.61 t ha^{-1} and the highest TKW 45.8 g were observed for CCP Popkorn (Denmark). Grain quality was low for all winter wheat CCPs and varieties in both years, protein content varied from 97.7 to 117.6 mg kg^{-1}. The highest grain quality was found in 2020 for MV Elit (Hungary) with protein content 126.8 mg kg^{-1}, gluten content 227.0 mg kg^{-1}, and *Zeleny* index 49.0. Weed suppression ability (WSA) was different between populations and tightly related to the number of plants (winter hardiness) and tillering capacity. The lowest WSA at GS 87-92 had CCP MV Elit (29.9%) and the highest CCP Brandex (58.5%).

The results of investigations showed that the average grain yield (2018-2020) of spring wheat CCPs was not significantly different in comparison to the local spring wheat variety Uffo. CCP P1 (high gluten content) from Denmark had the highest protein and gluten content and can be interesting for organic farmers and grain producers in Latvia. Assessment wheat CCPs will be continued by adding newly created local CCPs and local varieties in the following years. Winter hardiness was the main agronomical trait which was closely linked to weed suppression ability and grain yield of winter wheat.

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BROADENING AND EXPLOITING THE GENETIC BASE OF WHITE LUPIN

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Keywords: drought tolerance, genetic diversity, genomic selection, lime tolerance, *Lupinus albus*

White lupin is a European crop with a long history of domestication and high potential interest for high-protein food or feedstuff. This report aims to summarize the research steps that were undertaken to (i) verify the extent of genetic diversity exploited by modern breeding, (ii) identify elite bitter-seed landraces and sweet-seed germplasm aimed to broaden the genetic base for European breeding, (iii) assess the genetic variation for tolerance to key abiotic stresses in the germplasm of the novel genetic base, and (iv) verify the potential of genomic models based on genotyping-by-sequencing (GBS) SNP data to select simultaneously and cost-efficiently for some complex traits. Molecular diversity patterns of 83 landraces from nine major historical cropping regions and 15 commercial varieties confirmed that modern plant breeding exploited only a modest part of the crop genetic variation. Germplasm evaluation experiments for adaptation to severe drought or calcareous soil revealed substantial genetic variation (Annicchiarico and Thami-Alami, 2012; Annicchiarico et al., 2018), which, along with other information, was exploited to identify four elite landraces and four elite, sweet-seed lines that acted as parents of a broadly-based population. Some 144 sweet-seed lines extracted from this population were evaluated for grain yield under severe drought in a managed environment of Italy and for adaptation to moderately calcareous soil in a spring-sown environment of the Netherlands and an autumn-sown environment of Greece. We report on the observed line variation for these traits, and on the construction of genomic selection models and their ability to predict the line adaptation to drought or lime soil based on cross validations. Genome-enabled models may be used also to select for tolerance to anthracnose and the sweet-seed trait.

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PERENNIAL CEREALS FOR ORGANIC AGRICULTURE

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The cultivation of perennial wheat might represent an economically and ecologically interesting option for extensive cultivation, particularly in marginal land. In autumn 2017, five breeding lines of perennial wheat (*Triticum aestivum* × *Thinopyrum intermedium*) and for comparison two varieties of annual wheat were sown at three sites in Bavaria. The five breeding lines were selected from a bulk originating from Washington State University. Other plots were additionally sown with white clover and subterranean clover. Due to poor soil quality at the three sites, annual wheat can only be grown to a limited extent. In 2018, the yield of the perennial breeding lines was 49 to 96 % of the annual cv. 'Capo', which reached an average of 17.4 dt/ha. In 2019, the yield was 9 to 38 % of 'Capo', which reached an average of 10.8 dt/ha, showing large differences between the locations. The autumn re-emergence was significantly affected by the severe drought at all sites in 2018 and 2019 and showed differences between the lines up to a total failure at one site. In the third year, the yield of the breeding lines was very low, thus a third year of cultivation cannot be recommended under these climatic and soil conditions. The yields of the plots with under-sown clover were significantly higher in the third year. A mixture with a low growing clover species is recommended because of better weed suppression.

An important aspect for the production of perennial wheat is its intensive and deep root system that should increase organic soil matter, soil life and improve soil structure. Soil samples were taken each spring from annual wheat plots, perennial line mixture and perennial line mixture plus white clover. The three-year investigation already revealed some interesting tendencies. For example, in very sandy subsoil of one location, a significant increase of soil organic carbon in the order perennial with clover – perennial – annual was found. Moreover, two of the three locations showed a significant increase of microbial biomass in the same order both in top soil and subsoil. Number of earthworms was up to twice as high in perennial relative to annual wheat. Field trials with perennial rye cv. 'Perenne' derived from an interspecific cross between

Secale cereale and *S. montanum* were carried out from 2012 to 2015 at BOKU. Regular cuttings were done between stem elongation (beginning of May) and anthesis (mid-June) in order to determine biomass yield and regrowth capability. Biomass yield of 'Perenne' in the early cuttings was between 70 and 95% compared to cv. 'Elego', but decreased to 45% after heading/anthesis for the two- and three-year crop stand. This decrease was mainly due to the reduced plant height (-45 cm) of the perennial crop (2^{nd} and 3^{rd} year) compared to the first year crop. Root mass in the three-year crop was significantly higher compared to 'Elego' and the first and second year 'Perenne', but mainly only in the top 20 cm. Generally, significantly inferior grain yield was obtained for 'Perenne', reaching only 53%, 26% and 15% for the 1^{st}, 2^{nd} and 3^{rd} year crop, respectively, compared to annual 'Elego' (5670 kg/ha). Similarly, a significant decrease was also observed for thousand grain weight (-32%) from the first to the third year of cultivation. Moreover, a higher number of ergot sclerotia was observed for the interspecific perennial rye hybrid compared to 'Elego'. Weed infestation was constantly increasing in the perennial crop making a cultivation of more than three years not recommendable.

To introgress the perennial cytoplasm of *Thinopyrum intermedium* into modern germplasm of common wheat, RGA carried out in 2019 and 2020 several crosses between *T. intermedium* and common wheat. The aim of this work is to develop superior perennial amphidiploids in terms of fertility and other agronomic traits which are important for organic agriculture (e.g. disease resistance and improved nitrogen use efficiency).

Summarized, perennial cereals – best in mixture with clover species – are an interesting option for the production in organic agriculture especially on marginal sites in order to reduce erosion and improve soil fertility.

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VARIETAL KEY-TRAITS TO OPTIMISE AGRONOMIC PERFORMANCE OF WINTER WHEAT - PEA MIXTURES

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Keywords: breeding criteria, cultivars, intercropping, yield, protein content

Among factors influencing the performance of bi-specific mixtures stands the choice of varieties within species. In bread wheat - field pea mixtures, synchronization of maturities (for a simultaneous harvest of both species), resistance to lodging (of the wheat variety), resistance to seed breakage (in the pea variety), and differences in Thousand Seed Weights between both species (to facilitate sorting) are often considered. The impact of other varietal trait combinations on mixtures performance have rarely been looked at, so that too few reliable criteria are available to breeders to select for adaptation to mixtures in their breeding programs. One task of the EU H2020 Remix Project (www.remix-intercrops.eu) therefore aimed at the identification of morphological and/or functional key-traits likely to contribute to high performance of bi-specific mixtures.

We considered, in the field, the effect of variation in three varietal wheat traits combined to variation in three varietal pea traits, all usually assessed in sole crop (SC), on four agronomic performance indicators of the intercrop (IC). The varietal wheat traits were earliness at heading stage, canopy height at heading stage and tillering ability. The varietal pea traits were earliness at flowering, canopy height at the end of flowering, and flowering duration. We have chosen these six traits because we suspect they are heavily involved in plant-plant interactions. During the 2018/19 season, all possible binary mixtures of ten bread winter wheat genotypes with nine winter field pea genotypes were considered. The mixtures were full mixed on the row, with a unique ratio of the reference sowing densities in SC (wheat 50%-pea 75%). This led to 90 IC and 19 SC modalities in a complete randomized block design, sown in Organic Farming.

Analysis of the effect of combined varietal traits on the performance indicators ie wheat yield, pea yield, cumulative (wheat + pea) yield and wheat protein content showed that (i) wheat cultivar earliness and canopy height at heading stage had a significant impact on wheat protein content, but not on individual or cumulative yields. (ii) pea canopy height at the end of flowering and flowering duration had a significant impact on all performance indicators (iii) varietal traits choices for optimized performance were opposite whether [wheat and cumulative yields] or [pea yield and wheat protein content] were the desired performance. Four traits (wheat earliness, wheat height, pea height, and pea flowering duration) are therefore likely to be considered as selection criteria in breeding schemes for wheat/pea mixtures.

Breeding for culinary and nutritional quality

SCALING UP PARTICIPATION IN BREEDING FOR FLAVOR: ENGAGING FARMERS, GARDENERS, CULINARY PROFESSIONALS AND CONSUMERS

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Keywords: participatory plant breeding, culinary breeding

Responding to new climate realities necessitates the scaling up of participatory research, on-farm trials and organic breeding activities. In particular, as weather patterns become seemingly more erratic, it is critical that we develop methods for variety development that can lead to resilient cultivars over heterogeneous environmental conditions. The best strategy for dealing with this type of unpredictability is to test varieties over a wider range of environmental conditions, both within and across years. This points to a need for new models to develop varieties for organic farmers, as it is highly unlikely that either public sector institutions or larger seed companies will be able to establish formal breeding programs for a majority of important crops within a region.

There is a critical need to build capacity for farmers, plant breeders, culinary professionals and organic seed companies to work together to ensure that farmers' evolving needs and unique knowledge drive the development of the crop varieties available to them. New variety trialing and plant breeding methodologies, tools and analytics that can accommodate decentralized testing, collaborative leadership and large data sets involving multiple evaluators should be a priority. Successful breeding for regional adaptation depends on lowering the barrier to broad participation by making trial organization and participant communication more fluid and cost effective.

This presentation will describe an ongoing partnership between the Seed to Kitchen Collaborative at the University of Wisconsin-Madison, SeedLinked, a participatory variety trialing and breeding platform, and the Organic Seed Alliance. We are developing a professional community of practice for regional seed systems and breeding, as well as digital tools for farmers, independent plant breeders and seed companies to use to evaluate varieties over a wide range of environmental conditions for adaptation and culinary quality. This includes improvements in real-time information sharing, decentralized participatory methodology, analysis of large datasets from heterogeneous environments, and techniques for facilitating multi-stakeholder collaboration that will equip organic plant breeders to develop successful varieties for the organic community.

BREEDING FOR QUALITY: LESSONS LEARNED ON THREE VEGETABLE CROPS

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Keywords: plant breeding, vegetables, nutritional quality, mineral content, indirect selection

Food quality is gradually becoming more important. In particular organic consumers value the nutritive quality and taste of food. There is evidence that mineral content of a broad range of foods has much decreased over a period of60 years (Thomas, 2007). There is also evidence that breeding can result in lower mineral contents (Murphy et al. 2008). However, it also suggested that it is possible to look for a good balance in yield and nutrient in wheat (Moreira-Ascarrunz et al. 2016). Little, if any scientific evidence exists in the case of vegetable crops. In an inventory on a broad range of vegetable crops, a negative correlation between dry matter content and storability with taste under organic conditions was observed (Nuijten and Lammerts van Bueren et al. (2016). In a subsequent research project the relationships between yield, storability, taste and nutritive quality were studied in order to understand whether a balance among these crop traits is possible.

The research was conducted on two biodynamic farms (one with clay soil and one with sandy soil) with three crops (carrot, pumpkin and red cabbage) in two seasons (2017 and 2018). Per crop five cultivars were compared. On both farms the same trial set up was used with three replications and two harvest moments per season. Taste was evaluated on three moments: after harvest, during storage and after storage. Nutritional quality (content of eight minerals, dry matter content, Brix and EC) was measured after harvest. Yield was measured after harvest, after storage and recalculated as dry matter yield.

For all three crops, various interactions were observed for all traits between cultivar, location (soil), year and harvest moment. There seemed only a few consistent differences or patterns between categories of traits and between crops. Whereas large differences in fresh yield between cultivars was observed for all three crops, the differences in yield recalculated in dry matter were very small. Another general trend was that storability of the produce from the farm with clay soil was clearly better than the storability of the farm with sandy soil.

Also correlations between the traits often differed in various ways for the three crops. The strength of the correlations also differed between seasons and between locations. Clear negative correlations were observed between fresh yield with dry matter content and Brix for carrot and pumpkin. In the case of red cabbage these correlations were less strong but still negative. The correlations between EC and fresh yield differed much more between the three crops: EC correlated strongly negatively with yield for pumpkin, slightly negative for carrot and slightly positive for red cabbage. In the case of taste, most correlations with yield were not very high; mostly negative in the case of carrot and pumpkin, but mostly positive in the case of red cabbage.

Correlations were conducted between the eight minerals with dry matter content, Brix and EC in order to see whether indirect selection could be possible for mineral content. For each of the three crops different types of correlations were observed. In the case of carrot, EC showed strong positive correlations with the minerals K, Mg and S. In the case of pumpkin, dry matter content and Brix showed strong positive correlations with the minerals K, Mg, P, S and Zn. In the case of red cabbage, dry matter content showed a positive correlation with S and Zn, whereas EC showed a positive correlation with K and P.

These data suggest that in plant breeding more attention needs to be paid to nutritional quality. The data show that for each of the studied crops different approaches are needed to address nutritional quality in the breeding process. Indirect selection on mineral content seems easier to be achieved in the case of pumpkin whereas this may be more difficult for carrot and red cabbage.

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A CASE STUDY IN EFFICIENT METHODS TO EVALUATE AND SELECT FOR FLAVOR IN ORGANIC SWEET CORN BREEDING PROGRAMS

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Keywords: flavor, sweet corn, genomic selection, near infrared spectroscopy (NIRS), mating designs

Sweet corn (*Zea mays*) is the result of one or more mutations that result in more sugar and less starch in the kernels. For most sweet corn breeding programs, flavor is a critical selection criterion and improved flavor is primarily driven by increased kernel sugar. Currently, the most common method of evaluating flavor is by tasting entries at the fresh market eating stage and recording a qualitative rating. However, since the evaluation has to happen during a narrow maturity window, this method limits the evaluation of material at remote sites. Additionally, it is subjective.

Research was conducted on methods of evaluating sweet corn flavor in an organic breeding program to determine the following:

1. Was flavor a stable enough trait that evaluations in one environment would be predictive of flavor across many varied environments?
2. How reliable was the traditional bite testing methodology?
3. Could a near infrared spectroscopy (NIRS) model be effective in rapidly evaluating kernel sugars and polysaccharides?
4. Could traditional general combining ability (GCA) and genomic best linear unbiased prediction (GBLUP) models effectively predict the flavor of untested hybrids and synthetic open pollinated varieties based on the performance of related hybrids and parental inbreds?

To address those research questions, training trials of 40 *sugary enhancer* inbreds and 100 hybrid progeny generated from four 5x5 North Carolina Design II (NC DII) crossing blocks took place in 2015 and 2016 in 12 organic environments in total across California, Wisconsin and Oregon. Flavor was rated at the fresh eating stage on 1 to 5 scale, with 5 as the best. Kernels were also harvested at the fresh eating stage, freeze-dried, and ground. These samples were scanned with NIRS and a subset of samples were analyzed using sugar and starch assay kits. The inbred parents were sequenced to develop 4,137 distantly spaced SNPs. Stability of flavor across environments was compared using Spearman rank correlation, Wricke's ecovalence (w^2_i) and overlap of highest ranked entries across environments. Predicted flavor of untested hybrids was modeled using the GCAs of the inbred parents derived from the performance of their hybrid offspring. Additionally, flavor of untested hybrids was predicted using conditional expectation GBLUP models with only additive marker effects and with both additive and dominance marker effects. Predictions of untested synthetic open-pollinated entries were constructed using Wright's equation from the inbred performance and tested or predicted hybrid performance. In 2017, validation trials across five organic environments were conducted to determine predictive accuracy of these models.

Differences for both inbred and hybrid entries were seen for flavor. General combining ability differed among the inbreds. Entries were stable in rank for flavor across environments. Bite testing was well correlated with total kernel sugar content as measured by wet lab assays. While NIRS models were well correlated with glucose and fructose levels, the models did not correlate as well with sucrose and total starch levels. Both traditional GCA-based models and GBLUP models were accurate in predicting the actual flavors of untested hybrids. GBLUP models with only additive marker effects were as effective in predicting untested hybrids as GBLUP models with both additive and dominance marker effects. For prediction of the flavor of untested synthetic open-pollinated entries, both traditional and GBLUP models were moderately accurate, with the addition of dominance marker effects not adding to the accuracy of the models.

This study revealed that bite testing is an effective measurement of flavor, correlating well with total sugar content while also providing an opportunity to screen against any minor constituents that may create "off-flavors." While bite-testing is labor intensive, this study demonstrated that since flavor is stable across a range of environments, testing at a single site can be effective. While the NIRS models were able to correlate with glucose and fructose, they were not able to effectively predict all sugar and starch components and the current sample collection and preparation pipeline is not more efficient than bite testing. The use of structured mating designs such as NC DII allowed flavor predictions of untested hybrids. The use of markers and GBLUP models did not improve predictive ability beyond the traditional GCA model, but, unlike GCA models, does allow predictions of entries that do not have both parents represented in the mating design. The addition of inbred parents to the training trials allows the prediction of new open-pollinated varieties, but with less accuracy relative to the hybrid predictions.

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EFFECT OF THE RIPENING STAGE AND THE GROWING SYSTEM ON THE CONTENT OF MAIN FLAVONOIDS IN PEPPERS

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Keywords: *Capsicum* peppers, antioxidants, quercetin, luteolin, organic agriculture

Capsicum peppers are one of the most important vegetables in the world, which can be used both unripe and fully ripe. This crop has a wide genetic diversity, especially in Spain where we can find a large group of traditional varieties. Their nutritional quality is highly appreciated and recognized, based in phenolic compounds like the flavonoids quercetin and luteolin, among other bioactive compounds. Additionally, organic farming is an alternative system with an increasing demand due to the concern of the consumer for ecology and health (FAOSTAT, 2020). Nonetheless, there are no improved varieties for this kind of system which offers an opportunity to traditional varieties and landraces of peppers, which also encompass a high genetic diversity. The present work shows a preliminary study on the effect of the genotype, the ripening stage, the growing system, and their interaction on the levels of the main phenolic compounds in a selection of *Capsicum* peppers. The main phenolic compounds in unripe and fully ripe fruits from five *Capsicum annuum* Spanish varieties (Bierzo, Bola, Piquillo, Serrano and Valenciano), cultivated under organic and conventional growing practices in 2018 in Valencia (Spain), were analysed by high performance liquid chromatography (HPLC) (Bae, 2012). The genotype, ripening stage and growing system, as well as their interaction contributed considerably to the variation in phenolics, as previously described (Bae, 2012; Materska, 2005). The content of flavonoids in general was higher in the organic growing system, except for cv. Bola for luteolin at the unripe and fully ripe stage and for quercetin at the fully ripe stage. In general, the content of both compounds was similar or decreased during the ripening process, although some significant increases were found in Bierzo in both growing systems and Serrano in the organic system. Finally, a considerable interaction between the genotype and the growing system was found, suggesting there is an opportunity for selecting pepper accessions for organic cultivation with high content in phenolic compounds.

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NUTRACEUTICAL TRAITS AND SENSORY PROPRIERTIES OF "CIURIETTO" *(Brassica oleracea* var. *botrytis x Brassica oleracea* var*. italica)*

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Keywords: *Brassica oleracea* L., organic farming, functional food, antioxidant compounds, sensory properties

Brassica oleracea L. includes several economically relevant vegetables. These are also important for human nutrition. They showed nutraceutical traits and sensory properties related to several bioactive compounds, such as glucosinolates, polyphenols, anthocyanins, and vitamins. The richness of phytochemicals of the *B. oleracea* complex species (n=9) has been evidenced since some decades by several research teams which included the related crops among the superfood proposed for reducing chronical-degenerative diseases, as such as the cancer.

To evaluate the nutraceutical traits of some Sicilian landraces, we evaluated, within the BRESOV (Breeding for Resilient, Efficient and Sustainable Organic Vegetable Production, H2020 European project), five accessions of 'Ciurietto'. They distinguish themselves for the harvesting time of the curds, and for this reason, they are locally denominated by the months: 'Iannarino' (January), 'Friarolo' (February), 'Maiolino' (May) or by special holydays, like as "Saint Martin day" (beginning of November) or "Christmas day".

The 'Ciurietto' is considered a "*Culton*" of the violet cauliflower group; it seems to be originated by the crossing of broccoli (*Brassica oleracea* var. *italica*) and cauliflowers (*Brassica oleracea* var. *botrytis*). It is a typical Sicilian landrace, very widespread in South-East Sicily for its interesting culinary traits.

The trial was carried out with organic cultivation system, during the autumn - winter seasons in a greenhouse located near Ragusa.

The aim of this work was to evaluate the morpho-biometric parameters, and nutraceutical and organoleptic traits [antioxidant capacity, total polyphenols, total soluble solids (TSS, °Brix)] of five accessions of 'Ciurietto'

The 'Ciurietto' landraces showed very interesting traits, especially for high levels of TSS, that allow their uses for broccoli genetic improvement to obtain high quality food.

NUTRITIONAL AND CULINARY VALUE OF SOME IMPROVED PEPPER GENOTYPES *(Capsicum annuum)* CULTIVATED IN ECOLOGICAL SYSTEM

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Keywords: organic, carotenoid, lycopene, quality

The market request for organic vegetable has grown recently for their positive impact of healthy diets. Consumers have progressively shown preferences for various combinations of colour, size and shape of pepper fruits. Facilitating communication, collaboration, and participation in selection of cultivars with superior performance, flavour, texture, and culinary attributes can represent a key tool in breeding for nutritional and culinary traits. The current research started from the premise that organic production involves the achievement of adequate nutritional and culinary quality of pepper fruits. Several fruit quality traits, like total soluble solids, Vitamin C, colour (carotene, and chlorophyll content), dry matter and pericarp thickness, all responsible for culinary quality will be explored in this study.

Agricultural practices and intensive breeding focussed on yield and stress tolerance has indirectly led to reduction in nutrition and flavour of the produce. Complex approaches including screening of consumer preferences, phenotyping, use of modern genomics and analytical chemistry tools in breeding, together to participatory farmer-breeder-chef-consumer collaborations can represent a strategy to facilitate development of next generation of crops aimed to meet the growing demands of safe and nutritionally vegetables featured by culinary standards as good flavour, colour, aroma and texture. The study was conducted to investigate traits related culinary quality of pepper genotypes especially in the ripening phase of fruits, to select the best resources for breeding programs.

The biological material (9 genotypes of *Capsicum annum*) was harvested in august. Research was carried out on organic sweet pepper (*Capsicum annum* L. *ssp. annum*) cultivated in open field during 2019 and 2020 at the experimental stations of Vegetable Research Development Station of Bacau (46°580577” N, 26°953322” E, 158.96 m a.s.l.). The pepper genotypes were cultivated on clayey chambic chernozem soil with the following characteristics: pH 6.8; 2.6% organic matter; 0,150% N, 116 ppm P (mobile), 195 ppm K (mobile).

Comparing the average values of the total dry matter content, it is noticed a significant difference, considering that in 2019 the sample collected presented an almost double content (13.54%) vs. (6.95%) for samples collected in 2020.

Analyzing from a quantitative point of view the genotypes of *Capsicum annum* cultivated in 2020, a superior antioxidant value can be noticed in the 8, 9 and 5 genotypes with a content in β – carotene that varied between 10.32 mg · 100 g^{-1} to 5.37 mg · 100 g^{-1} and in lycopene with limits between 4.99 mg · 100 g^{-1} for G8 and 3.83 mg · 100 g^{-1} for G5. Also, genotypes G9, G8, G7, G6 and G5 are highlighted by a content high in vitamin C between 286.88 mg · 100 g^{-1} and 107.36 mg · 100 g^{-1}.

Genotype 8,9, and 5 cultivated in 2019 had a high content of carotene (10.32 mg · 100 g^{-1}, 6.99 mg · 100 g^{-1} and 5.37 mg · 100 g^{-1}) in lycopene (4.99 mg · 100 g^{-1} in G8, 1.75 mg · 100 g^{-1} in G9 and 3.83 mg · 100 g^{-1} in G5) and in vitamin C (286.88 mg · 100 g^{-1} in G9, 268.16 mg · 100 g^{-1} in G8 and 248.16 mg · 100 g^{-1} in G7).

Spectrophotometric analysis revealed the presence of chlorophyll a, chlorophyll b and xanthophylls in all genotypes analyzed with mean values of 4.25 mg · 100 g^{-1}, 5.57 mg · 100 g^{-1} and 5.8 mg · 100 g^{-1}. Significant statistical differences were also noticed in relation to the mean values of all genotypes according to year of cultivation and different conditions for most parameters.

Among the chemical compounds present in organic sweet pepper, the amount of β-carotene and lycopene seem to be parameters that improve the culinary value of pepper production based on the nutritional benefits obtained from their consumption.

EXPLORING PORTUGUESE MAIZE LANDRACES AS FRESH MAIZE

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Keywords: culinary breeding, maize, landraces, organic agriculture

The concept of culinary breeding aims to identify, discover and make accessible new germplasm in which consumers and chefs are already accustomed to purchasing or cooking. Educating the public and farmers about the importance of producing and consuming products of organic origin is another goal of the concept of culinary breeding.

The aim of this work was to make a sensory analysis with five maize landraces grown in organic agriculture. Ears from field plots were harvested during kernel milk stage and kept in cold storage. The frozen ears of each landrace were boiled separately. Afterwards ears were cut and provided to a panel of consumers that classified the color, texture and flavor among other traits. It was also requested to know what the purchase intention would be for each landrace. The evaluate traits were classified in a range of 1 to 9 (1-dislike completely versus 9 – like entirely). A total of 30 people participated in the evaluation. ANOVA and Post hoc comparison were applied.

The main results indicate that the color average was 6.1±2.17, taste ranged from 5.4±2.11, texture was 5.3±2.10 and global appreciation was 5.6±1.97 and buying intention of 2.9±1.24

Living soil – plant interactions

SOWING THE RIGHT SEEDS FOR SUSTAINABLE AGRICULTURE

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Keywords: seed microbiome

The plant microbiome is crucial for growth and health (Berg & Raaijmakers, 2018). While the microbiome in the rhizo- and phyllosphere is well studied in this context, seeds were often considered as reservoir for pathogens or as free of microorganisms. However, recent studies reveal an unexpected microbial diversity and abundance within seeds. Moreover, they showed a vertical transmission of a core microbiome, especially plant beneficial bacteria (Adam et al., 2016; Rybakova et al., 2017). Soil type, climate, geography and plant genotype were identified as main drivers of the seed microbiota. Within millennia of domestication, crops and their seeds underwent traceably many different adaptive trends, allowing rapid speciation and divergence that lead to phenotypic and genotypic distinction to their wild ancestors. During those dynamics, also the microbiomes have secretly co-evolved with the host plants (Wassermann et al., 2019). In seeds of Alpine plants, which we studied to understand the native seed-microbe interaction, they form a beneficial network with archaea. In contrast, fungi represent an antagonistic component. Breeding changed the plants towards productivity and resistance; interestingly, this is reflected in the seed microbiota as well. This resulted in diversity loss, which has consequences for one health issues. To restore microbial diversity, bacterial seed treatments can be designed (Matsumoto et al., 2021). Those seed biologicals can be harnessed for sustainable agricultural approaches by improving stress tolerance and resilience of modern crops.

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BACTERIAL SEED COMMUNITIES IN SUGAR BEET ARE INFLUENCED BY PROPAGATION SITE AND GENOTYPE

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Keywords: microbiome, *Beta vulgaris*, tolerance, *Rhizoctonia*

Sugar beet (*Beta vulgaris* L.) is the most important regional source of sucrose in moderate climates, with Europe and Russia being the core production area worldwide. Recently, an important role of the plant microbiota for resistance breeding was identified. We investigated bacterial seed communities of five different sugar beet cultivars with different degree of tolerance towards *Rhizoctonia solani* J.G. KÜHN, originating from two different propagation sites using 16S rRNA amplicon sequencing, as well as *in vitro* community change during germination. Bacterial seed communities were dominated by *Pseudomonas* and *Pantoea*, together ranging with an abundance between 20-67% of the total seed community. Additional genera, contributing to a variable extent to the seed community, were *Paenibacillus* (0-25%), *Sphingomonas* (0.1-17%) and *Massilia* (0.2-11%) Genotype and propagation site both affected community composition, alpha and beta diversity indices. Different cultivars shared a core community representing 80-91% of the bacterial seed community. Seeds of *Rhizoctonia*-tolerant cultivars contain a higher relative abundance of the genera *Paenibacillus*, *Kosakonia*, and *Enterobacter*. The majority of seed endophytes (63-83%) survives the process of germination, representing dominant taxa of seeds but with a community shift towards *Enterobacteriaceae*. Bacterial alpha diversity is higher in seeds than in seedling roots, indicating vacant niches in the young seedling for substrate-derived microorganisms. Our results demonstrate the compositional plasticity of bacterial seed microbiomes using sugar beet as a model plant, highlighting core taxa and responders to breeding for tolerance towards *R.solani*. This can further be translated into microbiome management strategies for establishing more sustainable agricultural practices in sugar beet breeding and cultivation.

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SEED ENDOPHYTES ISOLATED FROM SOYBEAN AND THEIR APPLICATION FOR BIOCONTROL AND PLANT GROWTH STIMULATION

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Keywords: endophytes, soybean, *Bacillus*, transcriptomics

Soybeans are an important source of proteins and fatty acids in human and animal nutrition. In 2019, the EU harvested almost 3 million tons of soybeans from 0.9 million hectares, which corresponds to about 1% of the harvested area in the major soybean-growing countries USA, Brazil and Argentina combined. Almost all imported soybeans are genetically modified to be resistant to glyphosate. In Europe, there is still a high demand for non-GM soybean as well as of early maturing soybeans with higher protein content.

To overcome some of the barriers to increase soybean production under European conditions, plant-associated microorganisms could be applied to combat diseases and to support resilience against abiotic stresses. Particularly bacterial endophytes have shown promising plant growth-promoting or resilience-enhancing activities. An important reservoir for endophytes is seeds. Seed endophytes have the potential to establish themselves in the plant microbiome after germination and tightly interact with the plant.

From five different soybean varieties, compromising varieties with different maturity properties as well having different oil and protein content, 287 bacterial endophytes were isolated. The endophytes were isolated during seed germination from surface-sterilized seeds. Most of the isolates belong to four genera: *Bacillus* (79), *Pseudomonas* (48), *Pantoea* (34) and *Paenibacillus* (29).

The strains were tested for germination improvement under in vitro conditions and in soil. From the 79 *Bacillus* isolates, 29 showed promising results in regard to germination improvement. The 16 best performing *Bacillus* strains and two *Paenibacillus* strains were further tested for their plant growth-promoting capacities under controlled conditions in a growing chamber. One *Bacillus* strain significantly improved plant biomass and the number of root forks after seven weeks of growth, which was selected for further plant transcriptome analysis. Additionally, potential biocontrol activities against *Fusarium oxysporum*, *Rhizoctonia solani*, *Botrytis cinerea*, *Sclerotinia sclerotiorum*, *Pyrenophora tritici* and *Phytophthora infestans* were tested in plate assays. For the control of P. *infestans* a detached leaf assay was performed. One *Bacillus* strain was selected, which showed in the confrontation assays activity against *Rhizoctonia solani*, *Botrytis cinerea*, *Sclerotinia sclerotiorum*, *Pyrenophora tritici* and *Phytophthora infestans*.

A transcriptome analysis was performed to identify genes that are regulated in soybean seeds after inoculation with the two selected *Bacillus strains*, one biocontrol strain and one plant growth- promoting strain. Soybean seeds were either inoculated with one of the two strains or left uninoculated (control) and placed in potting soil at 12°C or 18°C. After 24 and 48 hours the seeds were taken out and the RNA was extracted. The strain, which showed biocontrol activity, activated transcripts involved in plant defense like after 24 hours at 18°C. After 48 hours at 18°C transcripts involved in germination were activated in comparison to the control treatment. At 12°C no differences between the inoculated seeds and the control treatment were found. Seeds inoculated with second strain only showed a minor effect in plant gene expression, and no clear pathways could be assigned. The up- or down-regulation of different genes involved in plant defense and plant hormone production is currently validated. The combination of data from functional tests, plant transcriptomics and endophyte genome information, we expect to elucidate the mechanisms involved in biocontrol and the interaction with the plant.

PUMPKIN BREEDING SHAPES THE SEED MICROBIOME

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Keywords: plant-microbe interactions, *Cucurbitaceae*, amplicon sequencing, seed microbiome, microbiome tracking

Plants and pant seeds are colonized by a rich microbial community. Plant breeding was just recently discovered to directly and indirectly shape and select seed associated communities. We followed a breeding line of Styrian oil pumpkin (*Cucurbita pepo* L. subsp. *pepo* var. *styriaca Greb*.) using high throughput amplicon sequencing of the bacterial (16S) and fungal (ITS1) seed microbiome. Sown seeds, rhizosphere, bulk soil and progeny seeds from six cultivars were analysed. Seeds were found to generally carry a lower microbial diversity compared to rhizosphere or bulk soil samples. The distinct seed community was characterized especially by a high *Enterobacteriaceae* (40- 83%) abundance. Applying microbiome tracking, we found that bacterial taxa were mainly transferred from sown seeds to progeny seeds, while fungal taxa found on the progeny seeds for the most part originated from soil. Moreover, plant beneficial taxa (e.g. *Bacillaceae, Burkholderiaceae, Pseudomonadaceae*) were observed to be transmitted onto the progeny seeds. Our study highlights the complex assembly of seed microbial communities across different cultivars and along a three-way cross hybrid breeding line. Moreover, the importance of a consideration of plant associated microbiomes during breeding was demonstrated.

SPATIO-TEMPORAL HETEROGENEITY IN THE ROOT-MICROBIOTA OF GRAPE VINE: A *MICROBIAL TERROIR* IN VINEYARDS

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Keywords: amplicon sequencing, endospheric microbiote, microbial biogeography, microbial terroir, vineyard

A collaborative research with a famous Bordeaux vineyard (Château Palmer, Margaux, France) has emerged from the beginning of the year 2017 from questions about the role the microorganisms from the field to the cellar in the context of biodynamic practices. Among the methods of organic farming, the biodynamic method is the one that goes the furthest in a holistic approach, both in its basic ideas and in practice (Geier *et al*., 2016). Not addressed by mainstream science, the scientific biodynamic approach remains scattered (Foyer, 2018). An opportunity to bring biodynamics closer to the holobiont approach (Vandenkoornhuyse *et al*., 2015), a rapidly expanding scientific field in ecosystems, has been initiated at Château Palmer by a microbiological definition of the *terroir*.

The *terroir* of vineyards is traditionally defined from bedrock and related soil characteristics, topography and climate in a given region (Van Leeuwen and Seguin 2006). However, recent studies have introduced the importance of adding the microorganisms community pattern of a vineyard to better characterise the spirit of a wine and thus defined the *microbial terroir* (Bokulich *et al*. 2014; Gilbert, van der Lelie and Zarraonaindia 2014). Most studies on the biogeography of microorganisms associated with vine plants have focused on large scales (e.g. over 100km) and analysed the bulk soil and the rhizosphere. In this study, we aimed to innovatively challenge and transpose the idea of an existing *microbial terroir* at a local scale (i.e. inter-parcel and intra-parcel analyses) focusing on the root-microbiota endosphere (i.e. microorganisms having passed the root physical barrier and plant-immune system). We made four sampling campaigns across 37 parcels distributed throughout the domain to investigate changes in the vine microbiota over space and time (2 seasons for 2 years). We analysed bacterial and fungal-root microbiota composition using amplicon mass sequencing of cleaned root samples. Advanced statistical analyses including spatial analyses were performed to underline the drivers of the spatial heterogeneity of the root-microbiota composition over time.

Preliminary results obtained for only one sampling campaign (June 2018) showed that the root microbiota of the vine plants were dominated by four major phyla: the Proteobacteria and the Bacteroidetes accounting for almost 90% (relative abundance) of the bacteria community and the Ascomycota and the Basidiomycota (almost 90% of the fungi). When analysing key drivers of the two microbial communities, we showed significant effects of age, grape variety and pH on both microbial community in different ways. Indeed, we noticed shifts of microbial communities as well as microbial enrichment with pH and grape variety on the entire bacterial and fungal communities respectively. The key drivers of both microbial communities changed when further analysing the communities at the phylum level. As we only analysed so far the first sampling campaign, we need to strengthen these very preliminary results with the third sampling times left.

Overall, our results will improve our understanding of microbial assembly rules depending on the vine phenology, and illustrate the relative importance of several soil- and plant-specific factors (e.g. soil pH, plant age) in shaping the microbial assemblages. The factor plant age may involve age of the vine plants, grafting practices as well as rootstock genotypes (the range of vine age is from 1 to 60 years old). Because we showed that changes in microbial communities exist at the level of a single vineyard, it is rational to propose that understanding the complex interactions between bacteria, fungi and the vine plants could help vine-growers adjust their practices. Sustainable practices, which are deemed to improve microbial diversity, could intensify the specificity of a vine (*microbial terroir*) and enhance final product quality.

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PHYSIOLOGICAL AND GROWTH RESPONSES OF PEA INTERCROPPED WHEAT CULTIVARS

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Keywords: intercrops, plant physiology, soil microbiome activity, winter wheat

Interest is emerging in ecological intensification directed towards sustainable crop production. An experiment was conducted to assess soil microbial aspects, physiological and growth responses of wheat intercropped with pea. In conventional and organic farming systems the effect of winter wheat cultivars (*Triticum aestivum* L.; 'Mv Nádor', 'Mv Kolompos', YQCCP-composite cross population) and pea (*Pisum sativum* L. 'Aviron') intercropping was investigated on the functional diversity of rhizosphere microorganisms and root colonization of arbuscular mycorrhizal fungi (AMF) in relation to physiological parameters of wheat.

The $pH_{(KCl)}$, AL-P_2O_5, total N values, AL-K_2O and humus content of organic soils were significantly higher compared to that of conventional ones. AMF colonization of YQCCP population was higher in organic farming soils than in conventional ones. The intensity of AMF colonization was poor in roots of wheat genotypes, while it was high in pea roots. The principal component analysis of the microbial community-level physiological profiles generated by Biolog EcoPlate showed a slight separation of the organic and conventional samples. Soils with pea showed higher average catabolic response for organic acids but polymers were utilized weaker than in samples without pea. Chlorophyll content (SPAD) of wheat had a higher extent in conventional field than in organic farming, while pea caused a positive effect on SPAD, N-, P-, Cu-, Zn-, and K- content in wheat shoots.

Our data confirmed earlier results showing that organic management improved soil quality and functionality of soil microbial populations. Cereal-pea intercropping improved the physiological status of wheat and enzyme activities of soil microbial populations.

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DRIVERS OF ENDOSPHERIC ROOT MICROBIOTA ASSEMBLY OF ON-FARM SELECTED TOMATO IN AGROFORESTRY

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Keywords: agroforestry, organic breeding, microbiome, tomato

As a growing consideration for plant microbiome and its implication for breeding is rising, participatory research is more than ever necessary to locally adapt plants to the diversity of organic systems, in the way that it combines scientific approach and farmers' knowledge. On-farm plant breeding allows a rapid and continuous plant adaptation which could be enhanced by unraveling micro-organisms transmission across generations.

With this study, we aim at understanding the main drivers of the endospheric root microbiota assembly under contrasted agroforestry conditions, while considering on-farm selected plants. Using an integrative approach based on amplicon sequencing and a fungal strain collection linked with bioinformatic analysis (Lê Van 2017; Escudié 2018), we attempt to study the dynamics of microbiota recruitment. These preliminary results, obtained on a single generation of plants, will give a first view of how micro-organisms communities segregate depending on environmental conditions.

The main challenge of this study is to confront results previously described and obtained in controlled conditions (Ottesen 2013; Bergna 2018) to real and organic agriculture conditions, i.e. soil rather than sterile substrate and on-farm selected plants rather than commercial varieties. The study is based on two agroforestry farms in Southern France to address global warming challenges while understanding the main environmental drivers of the microbiota composition of two cultivars, which are « stabilised » populations of an autogamous species. These agroforestry systems and their shadeless controls offer very contrasted situations in which the root microbiota can be compared for plants bred on-farm.

Our work relies on 2 hypotheses:

– There is an effect of the variety on the tomato microbiota assembly;

– The set of environmental parameters (i.e. shading density, tree species, microclimate) encompassed by agroforestry influences the structuration of microorganisms.

On-farm breeding will be described as a holistic process in which plants represent biological systems shaped by genetic and microbiological processes. The structuration of root microbiota in these contrasted conditions would inspire general considerations for organic plant breeding aiming resilient cropping systems.

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ROOT MORPHOLOGICAL CHANGES DRIVEN BY STRESS FACTORS IN WHEAT-PEA INTERCROPS

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Keywords: cereal–legume intercrops, drought stress, *in situ* root characterization, winter wheat

The study of root morphology and dynamics is important in many aspects of plant nutrition, plant physiology, breeding and ecology. The root system plays a crucial role in water and nutrient uptake, affecting grain yield and quality, particularly under limited environments.

Root system architecture and functionality are essential for plant adaptation and productivity, but are often less studied because of the limited access to roots in the soil during the plant life cycle. The minirhizotron (MR) is a valuable non-destructive technique that allows the study of root architectural and morphological changes, including branching, depth distribution, longitudinal density, production, longevity, and mortality.

In sustainable agriculture, there is a growing interest in the use of intercropping systems, including cereal–legume mixtures, for improved land equivalent ratio, higher yields, better grain quality and protection from weeds.

In an EU project (ReMIX), the MR technique was used during the co-cultivation of winter wheat (*Triticum aestivum* L.; 'Mv Nádor', 'Mv Kolompos', YQCCP composite cross population) and pea (*Pisum sativum* L. 'Aviron'). Besides wheat sole crop, the mixture of wheat and pea was grown as additive intercrop in greenhouse containers under well-watered (60–70% field capacity; 17–20 v/v%) and drought stressed (dry near to the wilting point, ~9 v/v%) conditions.

Six 1000-litre cubic plastic containers were used, which were divided into two parts with a vertical plastic sheet to separate the wheat sole crop from the corresponding intercrop. Perpendicular to the sheet, three transparent polycarbonate MR tubes were placed horizontally in each container below the ground surface at a depth of 20, 50 and 80 cm.

The containers were filled with chernozem topsoil (0–30 cm) from an organic field characterized with 36.2% sand, 40.7% silt and 23.1% clay, pH_{H_2O} of 7.61, 16.3 mmol 100 g^{-1} cation exchange capacity, 1.70% $CaCO_3$, 3.36% humus content, 1822/364/459 mg kg^{-1} N/P/K content and 1.42 g cm^{-3} bulk density.

The soil water content (SWC) in the well-watered container was maintained with weekly irrigation. In the drought-stressed containers the soil was let to dry near to wilting point which was then slightly irrigated.

The MR measurements were performed on ten occasions throughout the growing season from the early vegetative to full maturity growth stages. The SWC was recorded with Decagon EC-5 sensors (Decagon Devices Inc., Pullman, WA, USA) connected to Em5b data loggers. The root images were recorded with a CI-600 rotary scanner (CID Bio-Science Inc., Camas, WA, USA), and then were analyzed using RootSnap! software from CID. The leaf chlorophyll content in SPAD value was estimated using Minolta SPAD-502 meter (Konica Minolta Inc., Osaka, Japan).

The MR-based root length (RL) and root surface area (RSA) were monitored during the growing period, and the wheat shoot dry mass (SDM) and grain yield (GY) were determined at maturity.

Image analysis revealed that RL and RSA sharply increased until flowering, followed by a moderate decrease during maturity stages. The presence of pea reduced the maximum RL and RSA for each wheat cultivar. Drought significantly increased the MR-based root size. The intercropping and drought treatment reduced wheat SDM and GY. The water deficit significantly ($P< 0.01$) reduced the SPAD value in each treatment.

In agreement with previous findings, our results demonstrated that the biomass and grain yield in additive intercrops tended to decrease under stressed conditions due to the strengthened intra- and interspecific competition by the overcrowded plant density. The application of the *in situ* MR method allows us an improved evaluation of root dynamics and plant responses under various cultivation and environmental conditions.

Acknowledgements

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PRELIMINARY STUDIES ON GENE EXPRESSION IN *CAPSICUM* PEPPERS ROOTS IN RESPONSE TO PHOSPHORUS DEFICIENCY

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Keywords: RNA, quantitative PCR, low P tolerance, nutrient deficiency, sustainable farming

Common peppers (*Capsicum annuum* L.) are one of the most economically important cultivated species of vegetables (and spices). They are grown worldwide for its consumption either for the fresh market, for cooking or industrial processing, in a plethora of agri-food uses. Thus, there are many varietal types grown in a range of soils and agroclimatic conditions (DeWitt and Bosland, 2009; Pereira-Dias et al., 2019). Thus, it would be of paramount importance to identify which ones can grow in soils poor in nutrients, in order to identify i) which ones may provide good response under low input conditions (i.e. sustainable or organic agricultural systems), as well as ii) the genes involved in such differential response.

In this regard, phosphorus is an essential macronutrient for plants, absorbed by roots through phosphate (Pi) transporters. Unfortunately, in some areas its availability is very low or nil, due to its low mobility and plants may suffer nutrient deficiency. Moreover, the use of P fertilizers in other agricultural systems is often excessive, which may cause eutrophication and contamination of aquifers (Fita et al., 2015). Therefore, the use of sources of variation with tolerance to low P, i.e. low P requirements, can be very useful for sustainable farming systems and breeding programs aimed to may be use affecting dramatically the yield.

Plants have different mechanisms of response to low concentration of different nutrients. It`s interesting, though, identify genes that might be expressed at different levels in response to these deficiencies. In pepper specifically, knowing the genes that are over-expressed in root might be a useful tool for breeding new lines tolerant to soils with low P available.

The present work is a preliminary study on the search for root-overexpressed candidate genes in response to phosphorus deficiency in peppers, as potential mechanisms of tolerance in peppers to the lack of phosphorus in the soil. For this work, young plants

(4-leave stage) of the genotypes cv. Adige and cv. Numex, selected from previous experiences (Pereira-Dias et al., 2020) were grown under control (1.5 mM) and low (0.5 mM) phosphorous conditions for three weeks. RNA was extracted from the roots, backtranscribed to cDNA and expression of some candidate genes was quantified by quantitative polymerase chain reaction (qPCR). Genes that act on phosphorus signaling pathways in various species of the Solanaceae family and that could potentially modify their expression in phosphorus deficiency were searched in silico. As a result, primers were synthesized for 35 candidate genes, from which 17 were validated. The results of the work showed no significant overexpression of the selected candidate genes in relation to the constitutive root Beta tubulin (β-TUB) gene under any of the conditions tested, only PHO1 gene and LPR1 gene showed little overexpression in Numex and Adige genotype, respectively. This results in gene expression were consequent with the low reduction in physiological traits as plant biomass and phosphorus content. Our results in this preliminary work suggest that: i) other candidate genes must be tested and/or ii) extreme P conditions must be compared in a short period of time (shock treatment with control P levels and no P). Also, we suggest a change in experimental design in treatments and sampling time to maximize gene expression and more easily detect changes in their expression.

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Organic production of high quality & healthy seed

IMPROVING CULTIVAR TESTING, SEED MULTIPLICATION & HEALTH FOR HIGH QUALITY SEEDS FOR THE ORGANIC SECTOR: OVERVIEW OF LIVESEED OUTCOMES

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Keywords: organic farming, cultivar testing, seed multiplication, seed health and quality, LIVESEED

LIVESEED aims to improve access to a wider pool of high-quality seeds for the organic farming sector by increasing volume and quality of organic seeds derived from cultivars tested and found suited to organic agriculture (OA).

Cultivars adapted to the diversity of organic farming systems and agroecological environments are key elements for boosting organic farms' productivity, their yield stability and the quality of their end products. Well organized breeding and post-registration cultivar testing networks can deliver information required by farmers to choose the cultivars best suited for their needs. To that end, Deliverable 2.1 gives an overview on the current organisational models for official registration and post-registration cultivar testing for Organic Agriculture over some EU countries. It has been completed by Delivrable 2.3 "Frugal, multi-actor and decentralised cultivar evaluation models for organic agriculture: methods, tools and guidelines". This report aims to foster the development of these networks by proving key resources to set them up and/or to optimize them. According to the objectives and constraints of targeted stakeholders, this report proposes innovative methodologies to develop appropriate organisations together with adapted experimental design, data collection and statistical methods for reliable results.

The new Organic Regulation EU 848/2018 recognises the priority of developing cultivars suitable to organic agriculture and introduces "Organic Varieties suited for OA" and "Organic Heterogeneous Material". To support its implementation, Liveseed produced two deliverables D2.4 and D2.8. Deliverable 2.4 provides guidelines and recommendations on improving testing procedures for organic varieties and inputs for the implementation of the 7-year temporary experiment planned on organic varieties, which will establish the criteria for the description of the characteristics of organic varieties and determine their production and marketing conditions. Deliverable 2.8 is proposing a toolbox for identification and description of Organic Heterogeneous Material". It provides, first, a summary of experiences of the temporary experiment 2014/150/EU allowing marketing of seed of heterogeneous populations of wheat, barley, oats and maize. Second, it clarifies the general requirements of OHM in terms of development and production compliant with organic principles. Third, it proposes and describes five key tools for characterisation of OHM that can be used in the notification process.

Organic seed production techniques remain poorly studied, with sporadic references that are quite difficult to locate. To tackle this issue, an inventory of existing technical and teaching materials has been conducted. Selected resources (50+ tools) have been made available on the online platform Organic FarmKnowledge (https://organic-farmknowledge.org/) together with 20+ practice abstracts. Establishing a professional network and knowledge sharing among practitioners across EU is the faster track to boost organic seed production. LIVESEED project organised a discovery journey through 4 cross-visits in Europe with the aim of documenting success stories of organic seed selection and production, enabling mutual learning among professionals, and also inspiring and initiating change (D2.2 and D5.7). Booklet #3, workshops, videos and practice abstracts spin of these cross-visits.

High quality seeds associated with vigorous seedlings condition the following crop performances and quality. In OA, preventive integrated approaches are crucial to guarantee organic plant and seed health. For the development of a novel organic seed health strategy (D2.7-in progress), two main cases are being developed as comprehensive study: (1) Alternaria sp. on carrot and (2) Bunt on winter bread wheat. On carrot, field and laboratory trials have elucidated the link between seed vigour and tolerance of seedlings to the disease. Regarding common bunt, research activities have focused on testing seed treatments and on the multiplication of resistant wheat varieties. Information on bunt management was shared with practitioners under different formats and channels. In addition, an inventory of seed health and seed quality related issues in European organic farming is being compiled to identify current issues and point to promising approaches to solve them in future. Side studies include: i) testing the effect of different growing environments (carrot) and of ageing (alfalfa and wheat) on seed microbiota ii) testing the effect of ageing on the pathogenic fungus Colletotrichum (on lupin seeds) and on biologicals applied to alfalfa seeds and iii) inquiring on the diversity of approaches to plant health in organic seed potato production.

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STATE OF ORGANIC SEED PRODUCTION IN THE UNITED STATES

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Keywords: organic seed, seed production, seed diversity, organic certification

Organic Seed Alliance's (OSA) *State of Organic Seed* (SOS) is an ongoing project to monitor the status of organic seed systems in the US. The purpose of the project is to measure the progress in increasing the availability, quality, and integrity of organic seed. The USDA's National Organic Program (NOP) requires the use of organic seed when commercially available (7 CFR § 205.204, 2003). However, according to the most recent SOS report, most organic farmers still rely on conventionally grown seed, as the organic seed supply is not keeping up with organic industry growth. (Hubbard and Zystro, 2016). The lack of a national variety registration system allows producers to grow and sell any variety of seed without a license as long as it is not restricted by intellectual property. This freedom to operate, coupled with diverse climates conducive to seed production of a wide range of species, provides the opportunity for producers to grow a diversity of types of certified organic seed in the US. The ongoing gap between the organic seed supply and demand raises the question of what is restricting the expansion of organic seed production and what opportunities could support further growth.

A report of the SOS findings is released every five years based on results of national surveys of organic farmers and other forms of data collection, including a full analysis of research investments in organic seed. The 2016 SOS report provided recommendations for ongoing progress, including highlighting the need for more training, economic opportunities, and processing infrastructure for organic seed producers. The next SOS report, slated for release in 2021, includes a national survey of certified organic seed producers. The aim of the survey is to assess who organic seed producers are, what resources they use, the challenges they face, and the opinions and experiences they have to share. This information will further inform recommendations to expand organic seed production in the US.

In 2020, the SOS project distributed surveys to certified organic seed producers in the US identified through the USDA/NOP directory of certified organic operations and OSA's internal contact database. Survey questions addressed scale of operations, annual revenues, crop types produced, resources and networks utilized, production challenges, and non-production (social, economic and policy) challenges. Respondents completed 70 surveys to date representing 25 % of the sample population.

In addition to seed production, about 41% of respondents also engaged in plant breeding. Likewise, about 41% of respondents engaged in direct retail sales of seed, whether their own or other producers. Respondents represented a range of scales, with the most commonly reported range for gross revenue being less than $25,000 USD with 34% of respondents, followed by over $300,000 in gross revenue, with 26% of respondents. About 40% of respondents grew conventional seed in addition to certified organic seed. Vegetable and ornamental crop seed were the most commonly and second most commonly grown crop categories respectively, with 74% and 48% of respondents respectively producing them. Seventy percent (70%) of organic seed producers were interested in increasing their capacity.

For producers, the top three production related challenges were: achieving adequate seed yields, estimating yields, and controlling weeds, with 65%, 62%, and 57% of respondents respectively indicating they were moderate or severe challenges. Climate change was also seen as a problem, with 86% of respondents stating that climate change will somewhat or significantly harm agriculture during their lifetime.

The top three non-production related challenges were: managing business activities, developing infrastructure, and farm business planning and finding and developing markets for organic seed (tied for third), with 50%, 41%, and 40% of respondents respectively indicating they were moderate or severe challenges. Intellectual property protections were also seen as a problem, with 71% of respondents considering plant utility patents to be somewhat or very harmful to organic seed production and 59% of respondents considering plant variety protections (PVP) to be somewhat or very harmful to organic seed production.

The seed producer survey is only one aspect of the SOS 2021 report. The full report will also include findings from the surveys of all organic producers, organic seed companies, and organic certifiers in addition to updates on research investments. This information collectively will serve as the basis for reflecting on trends over the past 15 years since the release of the first report, and will provide recommendations for future research, education and policy efforts to support ongoing improvements in organic seed availability, quality, and diversity.

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FROM SEED TO PLANT HEALTH – A BROADER PICTURE

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Keywords: organic farming, seed health, seed vigour, plant health, strategy

The management of seed-borne plant diseases currently mainly relies on seed treatments and resistance breeding. Both these approaches have in common that they fight off plant pathogens, either by disinfecting the seed or by breeding resistance genes into cultivars. Organic farming, and organic seed production in particular, may act as forerunners in basing plant health on broader microbial communities and crop ecology, rather than focussing solely on plant-pathogen interactions. Indeed, research emphasizing the role of microbiota, soil life, plant resilience and diversity (e.g. Hajjar et al., 2008; Vayssier-Taussat et al., 2014) converges with the ambition among actors of organic farming to develop holistic approaches to plant health (IFOAM Organics International, 2005). In this perspective, we aim at developing an organic plant health management strategy, drawing upon both scientific findings and empirical evidence from the field. The strategy is not a set of practical recommendations in the form of recipes, but rather gives the broad lines for approaches and suggestions for future research and development, as well as food for thought.

In the LIVESEED project, the issue of organic seed health and quality was addressed by an interdisciplinary combination of methods, ranging from qualitative inquiry among practitioners and researchers in the form of interviews and workshops, field and laboratory experiments testing the effects of seed treatments and seed aging, as well as desk studies. Efforts focussed mainly on the management of *Alternaria radicina* (causing damping-off and black rot) with carrot seeds and common bunt with winter wheat seeds as two core case studies. Exploratory studies were also performed on the rationales behind virus management with potato seed tubers and on survival of *Rhizobium* on alfalfa seeds during storage.

Firstly, an inventory of seed health and quality issues that are currently problematic in organic production was established, based on the input of European organic seed producers. This inventory serves as a starting point, revealing difficulties the strategy needs to address. Secondly, research on carrot has shown the beneficial effect of seed vigour for tolerance to *Alternaria*. While the causal explanation for this effect remains unclear, it points to the multifactorial dimension of plant health involving the resilience of the plants themselves or resilience conferred by the vigour of associated microbial communities. Thirdly, the inquiry into the issue of common bunt on wheat has revealed a diversity of practices are being tested by farmers to improve wheat health in general, ranging from on-farm probiotic seed treatments over mixed cropping to no-till. These observations were further substantiated by exploratory studies. Lastly, a several methodological improvements are proposed for further research into the topics addressed.

In summary and conclusion, overall results point to a number of approaches which are complementary to seed treatments and resistance breeding, and which take into account microbial communities and crop ecology as pillars of plant health. They also point to a need for research, both scientific and empirical, into what makes plant and seed health. As opposed to plant pathology focussing on disease, we might coin the term plant *salutology*, the science of plant health. In any case, the organic seed health strategy cannot be recipe-based, but will necessarily be intensive in knowledge and know-how, allow for adaptation to a diversity of contexts, constraints and environments.

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SEED TREATMENTS TO CONTROL COMMON BUNT

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Keywords: seed production, plant disease, *Tilletia caries*

To increase the toolbox to control common bunt (*Tilletia caries*) in wheat, the project SåGodt has over three ears tested different seed treatments, and evaluated the potential use in organic farming. The treatments included:

SonoSteam treatment, a method combining high pressure steam and ultrasound to break the layer of air around the seed. In this way, the heat is concentrated on the surface of the seed where the spores are, and the treatment can be stopped before the heat penetrates into vital parts of the seed. Equipment is commercially available with continuously throughput for a capacity of 1t/h, and 100% control can be achieved without significant effect on seed vigour. However, infecting seed with spores that was extracted from intact bunt sori treated with SonoSteam was able to infect the plants. This emphasizes that intact bunt sori must be effectively removed from seed lots before treatment, a measure most like also important for most other organic seed treatments.

E-Vita or **E-Pura** is a commercial available electron beam treatment available at several both mobile and fixed seed plans in Germany. Treatment with E-Vita at **Nordkorn Saaten** was able to control bunt without side effects on seed vigour. The treatment is based on wavelength of ~100nm which conflicts with the ban on ionising radiation in the EU regulation on organic farming. However, the German interpretation of the regulation allows the use of electron beam treatment in Germany.

Laminarin and **Fucoidan** are two polysaccharides found in brown algae. Laminarin was able to control bunt without side effects on seed vigour at a dose of 0.3% (lower dose was not tested), whereas fucoidan gave ambiguous results. Pelleting infested seed with brown algae powder reduced infections, but did not give full control.

Quinoa, sisal, corn-cockle and many other plants contains different **saponins** with anti fungal properties. Extracts from quinoa husks diluted in water significantly reduced bunt, but also reduced germination in the tested dose. Previous trials with crushed corn cockle seed (*Agrostemma githago*) and with sisal extracts (*Agave sisalana*) gave full control without negative side effects. It is concluded that saponins from plants has a potential as seed treatments, but more work is needed to find a commercial sound source of saponin and to refine the application.

Panoramix is a biological commercial product based on *Tricoderma spp*. At the recommended dose 4ml/kg, germination was significantly reduced and bunt infection not fully prevented.

Washing infested seed in water is a traditional treatment to remove spores from the seed. To overcome the need for post treatment drying, tests were performed to "wash" the seed in fine sieved dry dirt. It is indeed possible to remove spores in this way without affecting the seed vitality, but huge amount of spore-free dirt is needed to dilute the spore concentration on the seed surface to an insignificant level, and based on this, the method is not considered practical and economical compatible to other treatments.

Vinegar is a fermented product with a natural content of acetic acid of 5%. Acetic acid is harmful to both seed and spores, and the treatment is based on the fact that spores are placed on the surface of the seed, and therefore will be exposed to the acid before the acid reaches the vital parts of the seed. The seed surface can imbibe 20ml of 4% vinegar into the bran without significantly affecting seed vigour, and this dose gives full bunt control of the seed. However, the window between positive effect on control and negative side-effects on seed vigour is narrow, and higher amounts can under certain conditions be applied. If so, it is critical that the seed surface is re-dried removing any access liquid by re-drying before 60 seconds, as the acid will then enter vital parts of the seed and reduce seed vigour.

Application of **citric acid** was not able to control bunt without reducing seed vigour, most likely because citric acid in contrast to acetic acid does not evaporate, and therefore is still present on the seed surface at the time of germination.

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CARROT SEED VIGOUR, FIELD EMERGENCE AND TOLERANCE TO THE DAMPING-OFF PATHOGEN *Alternaria radicina*

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Keywords: *Alternaria radicina*, carrot, pathogen tolerance, seeds, vigour

In the field germinating seeds may experience stress as from moisture, drought temperature or pathogens. The ability of a seed lot to cope with this biotic and abiotic stress in the field is called seed vigour. Seed vigour is mainly tested in laboratory experiments by analysing the tolerance of a seed lot to abiotic stresses. In the frame of the LIFESEED project we tested if variation in seed vigour has also an effect on the tolerance to pathogens. As model we used carrot (*Daucus carota*) and the fungal pathogen *Alternaria radicina* which can cause both damping off disease and black rot.

To eliminate effects of genetics or seed production we used an organic produced commercial seed lot that was experimentally aged to obtain seed samples with different levels of vigour. The ageing was done by storing the seeds for 0, 2, 3 or 5 weeks under an elevated partial pressure of oxygen (EPPO) in steel tanks under 200 bar air at a relative humidity of 30%. Vigour was analysed in germination tests on filter paper, soil emergence in the lab and field emergence at three locations in Europe. With the field trial in the Netherlands also the yield was determined. An assay was developed to test tolerance to *A. radicina*. In short, seeds were dispersed in a Petri dish on a stack of three filter papers and wetted with different dilutions of the fungal spore suspension or water as control. The Petri dishes were placed in an incubator at 20°C. After 5, 7 and 10 days the seedlings were evaluated for infection by the pathogen. In the assay development seeds from a commercial lot were initially compared with lower vigour seeds that were mildly affected by a controlled deterioration treatment where the seeds were stored for five days at a high humidity and temperature (85%RH and 40°C). In a follow-up analysis EPPO treated seeds were compared with the control.

The experimental ageing resulted vigour decline, indicated by a slower germination and a slight decline in total seed germination when tested on filter paper, with a total germination of 91, 89, 84 and 83% for the 0, 2, 3 and 5 weeks treated seed lots. Also in the soil test the aged seeds performed less the longer the duration of the treatment, respectively 89, 73, 73 and 67% emergence. This difference was stronger compared to the germination on filter paper, indicative for more stress in soil.

Emergence in the field experiments differed considerably between the fields. In Switzerland the emergence was respectively 26, 14, 13 and 11%, in Germany 50, 40, 33 and 29% and in the Netherlands 82, 64, 57 and 54%. The yield in the Netherlands, harvested 54 days after sowing, was respectively 5.1, 4.7, 3.9 and 3.8 kg per 100 seeds sown.

Sensitivity of seed lots to *A. radicina* was tested using controlled deteriorated seeds, having slightly reduced vigour and control seeds. Without the presence of a pathogen, there was no effect of that treatment on total germination, except for a slower germination for lower vigour seeds. Addition of the spores gave a clear infection of the lower vigour seeds, visible as root decay, with a dilution of 10% and more concentrated spore suspensions. The control seeds were clearly more tolerant and only infected when the spore concentration was undiluted. The roots from the lower vigour seeds were also infected earlier in their development compared those from the high vigour seeds. A parallel test with a second *A. radicina* isolate showed comparable results, but here stronger dilutions gave already a pathogenic effect, while again the tolerance of the lower vigour seed lot was clearly less. Experiments with the EPPO aged seed samples showed a similar picture, the seeds with lower vigour germinated more slowly in the assay and were less tolerant to the pathogen. With the control seed sample more seedlings survived.

Storing carrot seeds under an elevated oxygen concentration, using the EPPO system, resulted in a decline in seed vigour, that can be used to analyse the effect of seed storage and vigour on field emergence, yield and sensitivity to the damping-off pathogen *A. radicina*. Although a mild effect is seen in a standard germination on filter paper, more extreme effects were observed when seedling emergence was tested in soil and in the field. A large difference in emergence was observed between the three different fields, indicative for the effect of frequently observed variation in environmental factors and stresses between field trials. An assay has been developed to analyse the effect of carrot seed vigour towards the *A. radicina* pathogen under more standardised laboratory conditions. Comparing sensitivity of the germinating seeds using various dilutions of the spore suspension is part of this assay.

CALORESPIROMETRY – A PROMISING PHENOTYPING TOOL TO ASSESS SEED VIABILITY BASED ON RESPIRATORY PARAMETERS

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Keywords: calorespirometry, alternative respiration, seed phenotyping, LIVESEED, germination

The organic agriculture sector demands more resilient plants, with yield stability under low input systems as well as under a variety of environmental constraints. To respond to these needs, modern breeding requires the development of new phenotyping techniques for screening complex traits. In this context, the establishment of calorespirometry as a screening tool focused on the activity of the alternative respiratory pathway, which is determined at the genomic level, highlights the interest in the application of this technique for rapid selection of highly resilient genotypes that require less input to achieve high production.

Calorespirometry, which simultaneously measures respiratory heat and CO_2 rates, has been proposed as a screening tool to assess metabolic and respiratory changes associated with cell reprogramming events. Considering that seed germination involves the activation of several metabolic pathways, including cellular respiration to provide the required energy, the objective of this work was to prove the usefulness of calorespirometry to assess seed viability by monitoring cellular respiration associated with the germination process.

Three commonly used pea cultivars (*Pisum sativum* L.) were selected for calorespirometry measurements and germination trials: cv. 'Rondo'(R), 'Torta de Quebrar' (TQ) and 'Maravilha D´América' (MA). Calorespirometric measurements were performed in a Multi-Cell Differential Scanning Calorimeter (MC-DSC, TA

Instruments). First, the effect of temperature on seed germination was evaluated after 16 h seed imbibition by running calorespirometric experiments in isothermal mode at 15, 20, 25 and 28°C. Then, to assess the involvement of the cytochrome and alternative respiratory pathways, inhibitors of both pathways were used: Rotenone (5 µM), and salicyl hydroxamic acid (SHAM, 10 mM), respectively. For validation of the calorespirometric method, a seed germination trial was conducted in parallel, at the same temperatures and using the same respiratory inhibitor concentrations. The results showed TQ had the highest germination rate across the temperatures tested.

Calorespirometric measurements revealed significant differences in metabolic heat rate, CO_2 production rate and the rate of biomass synthesis among the three cultivars. The cv. TQ showed the lowest values of both heat rate and CO_2 rate and highest germination rates, suggesting that early metabolic homeostasis for carbon and energy metabolism further modulates plant cell development and growth. In the experiments with inhibitors, rotenone caused significant differences in all the calorespirometric parameters, with cv. TQ showing lower values of respiratory heat rate, biomass synthesis rate and CO_2 production rate than cv. R and cv. MA. Hence, these results provide an important indication of the involvement of alternative respiration in seed germination.

The results achieved in this work demonstrate the suitability of calorespirometry as a screening tool to assess seed viability and to discriminate between different cultivars based on alternative respiration, without the need to grow plants under different temperature conditions in large trials, and therefore saving time, effort, and resources during the initial phases of plant breeding programs. To this end, current ongoing research at UEvora in the frame of the project LIVESEED is using calorespirometry-based phenotyping to investigate the link between a highly efficient alternative respiratory pathway during early stages of germination and high plant resilience in field conditions.

Organic agriculture is a valuable alternative to conventional agricultural practices, but needs plants with high plasticity and high resource-use efficiency in an increasingly variable climate. Organic agriculture thus has a strong need for a rapid method to select useful genotypes. The use of calorespirometry as a screening tool for characterizing the activities of both the cytochrome and alternative respiratory pathways as a function of temperature during seed germination highlights the ability of this method to aid in the rapid identification of markers for highly resilient genotypes for organic agriculture.

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BOOSTING COMMON BUNT MANAGEMENT IN EUROPE

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Keywords: common bunt, *Tilletia*, organic farming, plant health, wheat

Common bunt, caused by the fungi *Tilletia caries* and *T. foetida*, is a disease in wheat and related cereals. Starting from just a few spores on the seed, the disease can develop in the crop and considerably reduce grain yield and especially quality. The disease is mainly seed-borne, although it can also persist in soils. Techniques that allow the management of common bunt in organic farming - including sound crop management, observation, seed analyses and seed treatments – are well identified. However, when these are not put into practice, occurrences of common bunt still regularly devastate organic wheat crops. The research and development presented here follows two objectives: Firstly, collecting techniques already available for bunt management and developing appropriate formats to disseminate them. Secondly, exploring new approaches to bunt management, ranging from novel seed treatments to more holistic approaches to plant health.

An inquiry into common bunt management was performed over 4 years in the LIVESEED project, putting emphasis on the exchange of knowledge between European countries and across disciplinary boundaries. Meetings and workshops among researchers and practitioners allowed both for the exchange of knowledge on existing techniques for bunt management and for the emergence of unanswered questions. Field and laboratory trials were conducted to test and fine-tune seed treatments. Empirical experience with common bunt was explored through qualitative interviews. Particular attention was placed on farmers' varieties, which pose specific constraints.

As first outcome, several formats were developed for disseminating the knowledge on the combination of multiple practices that reduce the risk of common bunt, including workshops, websites (English: ITAB, 2020; also available in French and Hungarian), videos and Practice Abstracts. Specific knowledge gaps (e.g. on how to properly treat seeds with vinegar) or frequent practical shortcomings (e.g. thorough seed cleaning) were highlighted. We infer that reliable bunt management in organic farming requires specific knowledge on the disease cycle of the fungus, as well as practical and observation skills on behalf of practitioners.

As a second outcome, information on official thresholds for bunt spores in certified wheat seed in EU member states was retrieved, allowing for a comparison of national regulations. This also served as a basis for discussions on transparent, if not harmonized, rules for bunt management in organic wheat seed.

Thirdly, seed treatment examinations produced operational knowledge to optimize their application in organic agriculture. For instance, the effect of improper storage on the product CERALL, which is based on antagonistic microorganisms, was tested; as well as phytotoxic effects of different vinegar concentrations. Novel treatments, such as SonoSteam, Saponins and Laminarin were also investigated.

Unanswered questions for future research include: To what extent is bunt present in organic cropping systems without causing symptoms? What role does soil microbiota play in suppressing bunt? What types of plant defense mechanisms come into play? Are there allelopathic effects of previous or mixed crops in diversified crop rotation? Which farm-produced seed treatments may be efficient?

Further, findings on common bunt management will feed into a broader reflection on seed and plant health in organic systems.

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SUITABILITY OF POTATOES VARIETIES AND BREEDING CLONES FOR ORGANIC FARMING IN NORTH COURLAND REGION OF LATVIA

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Keywords: potato tuber yield, yield structure, potato diseases

The demand of organic potatoes products is increasing not only in Europe, but also in Latvia. The results of research showed that the production potential of potatoes is about 20-50% lower in organic fields compared to conventional or integrated systems. It is very important to select varieties suitable for organic system, characterized with high productivity and also resistance to pathogens. Productivity of potatoes depends on various factors: soil, amount of nutrition, weather conditions during vegetation and variety. Potatoes have relatively high nutritional requirements. Very important is development of root system. Advanced plant root system is a guarantee for uptake of nutrition. Specific morphological traits of plant, including development of roots mainly are depending from variety.

The aim of the research was to select potatoes varieties and to test suitability of breeding clones for organic system.

In the biological field the trial was arranged in 4 replicates, the variants were randomized. Area of the plot - 6.4 m², number of plants per plot - 25. In the spring before planting, the fields were milled and thinned. The potatoes were planted in the third decade of May, by hand and within a distance of 0.3 m between the tubers and 0.70 m between rows. Weeds were controlled by harrowing, while Colorado beetles (*Leptinotarsa decimlineata*) were collected by hand. Nine varieties and 10 breeding clones were under investigation: Monta, Rigonda, Lenora, Prelma, Brasla, Imanta, Magdalena, Jogla, Gundega, S07169 - 35, 2002 - 3317, 07131 - 15, S10063 -178, S10063 – 48, S09035-22, 19694.5, S07156-22, 19922.29, 2008 - 6.5. Potatoes varieties and breeding clones, were investigated in Institute of Agricultural Resources and Economics, (2018-2020). The main tasks of the research were estimation of tuber yield and structure, plant phenological phases, and resistance to pathogens. Obtained results proved significant difference between yields of varieties, tuber yield ranged from 15.9 to 29.22 t ha^{-1}. Highest productivity showed variety ‘Jogla’ (27.69 t ha^{-1}) and breeding lines clones S09035-22 (29.22 t ha^{-1}); S10063-128 (27.79 t ha^{-1}); 19922.29 (26.50 t ha^{-1}).

The potato varieties and breeding clones were assessed for late blight (*Phytophthora infestans*) and alternaria (*Alternaria solani*) resistence in field test (for replications) during the growing season. More resistant to late blight (*Phytophthora infestans*) was variety 'Jogla' and the most resistant clones to alternaria (*Alternaria solani*) 2008-6.5, 19922.29 and the variety 'Monta'.

The new varieties will be possible in after evaluation yield and quality of breeding clones suitable for growing in organic condition.

YIELD POTENTIAL IN ORGANIC AND CONVENTIONAL CEREAL SEED

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Keywords: seed production, variety trial

According to the EU seed regulation, cereal seed need to be able to germinate at least 85%, and in Denmark, national standards require a germination of 90-95% depending on the crop species. However, even when seed meets these standards, differences in germination vigour measured as germination speed exist. Pedersen et al. (1993) has shown that yield may differ up to 16% caused by differences in seed vigour in winter sown cereals, and also in spring barley it is shown that yield may differ up to 14% in seed lots that still meets the elevated Danish requirements for certified seed under conventional growing conditions (Emmeluth 1990, 1991). Under organic conditions, the effect is likely to be even higher, since especially weed competition is affected by the speed of emergence and early growth rate of the seedlings (Rasmussen and Rasmussen 2000). Müller (2013) showed that organic barley seed yielded 10-25% less compared with conventional seed of the same variety.

Some varieties of spring barley are produced by Nordic Seed in both organic and conventional quality. The seed is produced by different farmers but in general following the same drying schemes and post harvest handling in similar cleaning facilities. Therefore, seed samples are considered similar in most respects except for the growing conditions under organic and conventional conditions. Field trials was performed over three year in 2017-2019 with 3, 7 and 6 varieties included each year, and each year, each variety was sown from both 1-3 organic and 1-3 conventional propagated seed lots. Each year, 2-3 identical trials were conducted with the same seed lots in the same plot design of three replicates of 10m², and 350 plants/m². Field trials were grown under conventional sprayed conditions at Nordic Seed in 2017, 2018 and 2019 and under organic conditions at Nordic Seed in 2018 and 2019. At Agrologica, trials were sown under organic conditions in all years 2017-19. The trial at Agrologica 2018 was discarded due to draught and manganese deficiency. Growing conditions at Nordic Seed are good with clay loam soil with medium fertility, whereas conditions at Agrologica was poor sandy soils and especially in 2017 very low fertiliser level and high weed pressure. Lodging was not observed in neither condition.

Differences between varieties was significant in all trials, but the effect of organic versus conventional seed was not when all sites were included, and it cannot be concluded that conventional seed has better quality or results in lower yield. However, when analysing the data from each individual trial, significant differences were observed between seed grown organically or conventionally at the trials at Agrologica (ANOVA, p= 0.02), but not at Nordic Seed. It is possible that differences was only expressed under stressed low input growing conditions at Agrologica, and not at better growing conditions at Nordic Seed. However, we need further investigations to document this speculation.

Aknowledgements

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VINEGAR SEED TREATMENT TO CONTROL COMMON BUNT IN WHEAT

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Keywords: seed production, plant disease, *Tilletia caries*

Among integrated bunt management methods, vinegar seed treatment is able to control common bunt in wheat and leaf stripe in barley when used as a seed treatment in doses of 20 ml/kg (Borgen and Nielsen 2001, Saidi et al. 2001). White vinegar now has been approved for use as a seed treatment in organic production in the EU (EU 2019), which makes it relevant to develop the method for practical application. As an objective to further optimise vinegar treatments, dose-response trials with vinegar were done in the period 2017-2020 at Agrologica(DK), AGES(AT), ÖMKi(HU), NARDI(RO) and UBIOS(FR).

The effect of vinegar treatments depends on the concentration of acetic acid, the dose applied, and the duration of the treatment. Too high concentrations doses or durations harm seed germination, because excess liquid is gradually imbibed by kernels and reaches their vital parts. A dose of 20 ml/kg vinegar is enough to cover all parts of the grain, and the grain surface can absorb this amount without excess. When larger seed lots are treated and stored in a closed environment, evaporation of the vinegar is prevented, making the recommended dose and concentration of acid crucial. Post treatment drying may be needed depending on the initial humidity of the seed in order not to affect storability. However, the acetic acid needs time to harm spores, and if re-drying is included in the treatment procedure, it must be postponed some time to let the vinegar work. The more vinegar is applied to the seed, the shorter the treatment duration is needed. A treatment of 40-60 ml/kg without drying will harm germination, but re-drying in a way that seed gets below 2% increased humidity before 60 seconds after application will give full effect without harming germination. Consider that drying is a process that takes time depending on temperature and air flow. Therefore, time specifications must be adjusted individually to the given circumstances and the equipment available.

For larger scale production, equipment for fungicide seed treatment can be used, but for small scale production, spraying vinegar onto seed in a running cement drum or similar can be used for batch treatment.

Vinegar has been shown to control common bunt also in spelt and other hulled wheat species (Borgen unpublished), but the required dose is higher, which is feasible, as spelt can tolerate higher portions of vinegar. However, the optimal dose for hulled species is yet to be determined.

To further improve the method, it would be relevant to test the effect of reduced surface tension additives such as soap, saponin or other natural surfactants, as this may improve surface cover at lower doses. Also, it must be considered that most trials with vinegar have been made on small experimental seed samples, and the effect of scaling up, including the evaporation of acetic acid after treatment must be further investigated if implemented on commercial seed production level.

Acknowledgements

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EFFECTS OF MICROORGANISMS AND AMINO ACIDS ON ORGANIC SEEDS PRODUCTION OF TOMATO *(Solanum lycopersicum)*

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Keywords: cultivars, organic farming, fruit production, high temperatures, fruit set

Organic seed production of tomato is an important goal for seed companies interested to cover the gap for providing a good amount of high-quality organic seeds for satisfying the requests of the European growers. The BRESOV H2020 project is trying to cover this gap by several activities for increasing the quality seeds for organic farming by using biocontrol agent and amino acids provided by Itaka S.R.L.

In this frame we evaluated eight tomato cultivars in the frame of the H2020 Bresov (Breeding for Resilient, Efficient and Sustainable Organic Vegetable Production) project for organic seed production.

The growing cycle was carried out in an organic farm located in Gerbini (37°31'06.5"N 14°47'27.5"E) transplanting the plantlets in June. The experimental design adopted was split-plot with the main plot represented by the Itaka plant nutrition protocols (IP) based on Amino complex© and 3KO© (*Trichoderma harzianum*, *T. asperellum*, *T. atroviride*) products (IP0 = 0 g L^{-1}; IP1 = 1.5 g L^{-1}; IP2 = 3.0 g L^{-1}) and the sub-plot by genotype, and each thesis was represented by three replicates of fourteen plants each. Plants were placed at the crop density of 2 plants m^{-2}, along single rows 1m spaced each other.

During the growing cycle, the main phenological parameters, as such as the date of the third flowering of the second truss was recorded, the chlorophyl content of the leaves were registered by SPAD 502 Plus Chlorophyl meter. After 120 days from transplanting were harvested the fruits and the number and the weight of the ripped and unripped ones were registered. Thirty fruits per replicate were characterized for their fresh and dry weight, longitudinal and transversal dimensions, chromatic parameters (CIE L* a* b*) and the total soluble solids of the fruits were registered. At plant harvesting the height of plants, the number of leaves and trusses, as well as the parameters of tomato fruit and seed yield were registered. At plant harvesting the height of plants, the number of leaves and truss, as well as the parameters of tomato fruit and seed yield were registered. Fruits and seeds production were affected positively by the microorganisms utilized showing an interesting interaction plant nutrition protocol x genotype. A significant interaction between the two experimental factors analysed could be also related to the sub-optimal soil-climatic conditions as such as the high temperature and soil electric conductivity affected tomato fruit-setting.

THE CELL FUSION-FREE VEGETABLE LIST HELPS ORGANIC FARMERS TO FIND SUITABLE CULTIVARS

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Keywords: CMS, *Brassica*, varieties, positive-list, breeding

Many organic farmers want to cultivate vegetables free of artificial cell fusion. Cell fusions are used as a method to transfer the so-called ›cytoplasmic male sterility‹ (CMS) in cabbage species and chicory. The mother plant is made male sterile in a biotechnological process. CMS occurs naturally in many plants but is now almost exclusively introduced into the breeding lines in the laboratory using methods similar to genetic engineering. Therefore the technique is rejected for ethical reasons, because it does not comply with principles of organic farming (IFOAM Organics international 2017) and has been banned by several private organic labels. Though, especially in *Brassica* vegetables and some chicory species, many cultivars on the market were produced this way. For this reason farmers have difficulties to find out which cultivars are cell fusion-free, because the techniques are excluded from the GMO regulation and don't have to be labelled.

A consortium of FiBL, Bioland, Naturland, Bio Austria, Bio Suisse, Demeter and BNN published a list of vegetable cell fusion free cultivars (Positive list 2020, No.1179), suited for organic production for Central Europe. By consulting the list, farmers can find out if the varieties they want to plant are included or if there are suitable alternatives. The listed varieties must have at least one of the following assurances for freedom from cell fusion: written assurance from the breeder, flower morphological observation by a breeding expert, quantitative PCR analysis of seeds from a sealed original seed package or confirmation as an open-pollinated, seed-solid variety (e.g. according to the EU list of varieties).

The list was created with the support of the Liveseed project, is available in several languages and will be regularly complemented with more cultivars, especially from the Mediterranean region. It contains all available varieties of sugar loaf, chicory, cabbage and radicchio types that are not based on CMS transferred by cell fusion and helps to promote varieties that have emerged without critical breeding processes in the long term.

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Multi-actor & participatory approaches

SIMPLIFY COLLABORATION, AMPLIFY RESULTS: FACILITATING A DIVERSE SEED SYSTEM WITH A COLLABORATIVE DIGITAL PLATFORM

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Keywords: crowdsourcing, engagement, user experience, collaborative testing

Specialty crop seed movements have been gaining a lot of traction in recent years. By nature, this emerging independent and regional seed economy embraces a diversity of environments, managements, people, crops, and genetics, and is more decentralized. Perhaps most importantly, the emerging specialty crop seed movements are collaborative. Those factors make it much more resilient than the conventional consolidate seed economy. However, it is messier because it is also much more complex. In the last 10 years, we have seen a lot of breakthroughs in statistical models to facilitate the participatory development of new varieties for diverse agroecosystems. Unfortunately, the logistical barriers, including capturing broad engagement, remain the main roadblock of its expansion. In the last 3 years, we have been developing and piloting a platform model using mobile devices, cloud computing and crowdsourcing methods to dismantle some of those barriers. Our core objectives have been to 1) demonstrate discriminative ability of crowdsourced model; 2) remove participation barriers using digital means and instant data sharing; 3) heavily focus on the grower's experience within the platform, from mobile app to web app; and 4) connecting collective data across geography, time, and people to generate value to both sides of the specialty crop seed industry (growers and breeders) to boost participation. After 2 years of large testing, 1,800 growers participating in more than 300 trials, across more than 1000 varieties and 35 crops in North America, we have learned many lessons. We will share our challenging journey toward simplification and maximum engagement from trial results and data accuracy, participation rate, cost, user experience, and key features. We will also present our road map toward broader adoption and bringing additional value to all seed stakeholders.

FRUGAL, MULTI-ACTOR AND DECENTRALISED CULTIVAR EVALUATION MODELS FOR ORGANIC AGRICULTURE: METHODS, TOOLS AND GUIDELINES

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Keywords: cultivar evaluation, on-farm trials, multi-actor networks, frugal innovation, organic farming

Cultivar choice is the main crop-specific decision organic farmers can make in the absence of external input, yet this is supported by insufficient information. In conventional agriculture, post-registration cultivar evaluation is mainly performed on experimental sites and its results are used by extension services to provide variety recommendations to farmers. This system requires a great investment in logistics and infrastructure, however, is of limited relevance to organic farmers. In fact, performance ranking of cultivars can change whether the evaluation is done in conventional or in organic conditions. Moreover, organic food and farming systems are diversified, with many different crops being cultivated in diverse contexts and for different purposes and are exposed to higher environmental variability than conventional systems. Organic cultivar evaluation programmes are limited to few major crops and to the Countries where organic agriculture is already well developed.

In the framework of LIVESEED, several partners joined forces to co-design effective and innovative cultivar evaluation models, also keeping in mind their applicability in European countries with limited or no infrastructure, the potential and challenges of conducting on-farm and participatory trials, the issues of data quality and cost-efficiency. These models should encompass both social and technical dimensions and include the concepts of on-farm decentralized evaluation, participative and multi-actor networks and frugal innovation. A process based on the Concept-Knowledge theory (Le Masson et al., 2014) was implemented through several workshops and

webinars bringing together researchers from institutes of several European countries. This led to a strategy based on the objective and constraints, together with inspiring examples and crop specific protocols, to support the development of tailor-made solutions. These outcomes are described in a full report (LIVESEED deliverable D2.3).
In this proposed strategy, **participatory approaches** are not only ethically preferable, but essential to cover the wide range of needs and environmental conditions of organic farming, as well as to mobilise resources in a frugal framework. **Coordination and facilitation** of a collaborative network are fundamental and require appropriate skills and methods to act as innovation brokers and "catalysers" of empowerment.
For many constraints, there are **statistical methods** that can generate robust and useful decision-making data. Several scientifically validated experimental designs were proposed based on the types of data and specific constraints, for instance the number of cultivars to be tested, the number of farms involved and if replications are needed.
Economic models need to be chosen through exploring or combining different approaches, from public support, to subscription-based or supply-chain cost recovery models. The final model should be developed around and integrated into broader breeding programme financing strategies. In this respect, alternatives to the royalty-based breeding business models can be developed for organic cultivar testing, given their inappropriateness to the need to significantly diversify the pool of varieties for organic farming.
Finally, the concepts of a future solution have been drawn, proposing a new European model of cultivar testing based on a collaborative digital platform. **Integration of ICT technologies** can be a lever to facilitate frugal, highly inclusive and representative cultivar trialling infrastructures, as proven by existing initiatives (Brown et al., 2020, Van Etten et al., 2019) that will need to be further explored and potentially adapted to the European context.
Developing an effective cultivar testing infrastructure can reinforce the role of organic farming in being pivotal for a broader transition towards agroecological food and farming systems. Organic cultivar testing models must therefore be seen as a highly strategic objective the societal impact of which can, in the long run, be critical for the whole European agricultural sector.

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THE RIPPLE EFFECT OF PARTICIPATORY PLANT BREEDING: A CASE STUDY IN US OF ORGANIC SWEET CORN

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Keywords: organic seed, participatory plant breeding, sweet corn, variety release, seed systems

Participatory plant breeding (PPB) is a methodology where farmers, professional breeders, and other stakeholders collaborate in various stages of the breeding process. PPB is proposed as a promising method to breed for organic systems and address shortages in diversity and quantity of organic seed available (Shelton and Tracy, 2016). Arguments for the methodology include improving heritability by selecting under the environment of intended use, improving adoption through involvement of stakeholders in setting breeding objectives, and developing open pollinated varieties that can be continuously selected by farmers to improve adaptation (Dawson et al, 2008; Shelton and Tracy, 2016). In many cases the varieties developed through PPB are adopted by the farmers involved in the project, but few are registered or formally commercialized. This has resulted in a lack of knowledge as to what extent PPB is expanding farmers' access to organic seed and how many farmers are benefiting from individual PPB projects. Here we examine one case of a PPB developed sweet corn variety released in 2014.

In 2014, the release of a new PPB sweet corn (*Zea mays* L.) variety served as an opportunity to test the hypothesis that commercialization could expand access to a PPB variety while also providing revenue to support ongoing variety maintenance and stimulate additional breeding efforts. From 2008-2014 an organic farmer, a public breeding program, and non-profit collaborated to breed an open-pollinated, sugary enhanced (SE) sweet corn with traits that suited the farmer's needs (Shelton and Tracy, 2015). All three entities collaborated in all phases of breeding and decision making from prioritizing traits, to making selections in the field, to negotiating the naming and final release of the new variety, 'Who Get's Kissed?'. The breeding team collectively agreed to avoid intellectual property in order to allow diverse farmers and seed companies to grow and sell the variety and to encourage additional breeding efforts. The three entities collectively decided to release the variety for commercialization in partnership with the organic seed company, High Mowing Organic Seeds (HMOS), to expand access.

'Who get's kissed?' achieved the highest sales of a new release in the first year than any previous new release from HMOS and is offered today as organic seed by at least 14 seed companies, many of which source seed from HMOS. The breeding team has continued to maintain the variety quality through trials and stock seed production in partnership with an organic seed grower supported by the income from royalties from seed sales. At least three farmer-breeder projects utilized 'Who get's kissed?' as a breeding parent and one was released in 2020 as a new variety pledged under the Open Source Seed Initiative. The variety release and commercialization process served as a valuable learning opportunity for all four breeding partners (including HMOS) in assessing the time, costs, and impact benefits related to releasing a PPB variety.

Acknowledgements

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PARTICIPATORY BREEDING IN TOMATO IN SOUTHERN EUROPE IN THE FRAME OF ORGANIC FARMING: APPROACHES, PLANT POPULATIONS, RESULTS AND LESSONS LEARNED

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Keywords: tomato landraces, heterogenous materials, consumers, fruit quality, agronomic performance

Nowadays, modern cultivars dominate the production of vegetables, particularly F1 hybrids, even in organic production, due to the predominance of conventional companies in the seed sector. By contrast, traditional varieties have been abandoned in the last decades. However, these populations are recognized by their nutritional and organoleptic quality, and most of them were bred under the ancient low-input agriculture. In these regard, organic farming offers a good opportunity for these varieties as a better adaptation to organic conditions is expected in comparison to modern varieties, and consumers gradually relate organic farming to traditional varieties, better flavors and nutritional quality. Also, to promote their use increases varietal diversification, contributing to a more resilient agriculture. Finally, the use of heterogeneous populations (intra-varietal diversity) increases even more the whole agrodiversity of the food system. Within LIVESEED project, this work was aimed to compare results and pros&cons, of different approaches of tomato participatory breeding, plant populations and locations in Spain and Italy.

Three different working lines were developed during three years in Spain and Italy. In Spain, more than 250 landraces preselected from TRADITOM FP7 project were evaluated in Valencia (Mediterranean) and Villamartin (Cadiz, Southwest Andalusia), involving i) farmers and breeders for agronomic evaluation, ii) scientists and fruit analytics (sugars and acids by refractometer and HPLC, volatiles by GC/MS) and iii) taste panels with consumers in the process of evaluation and selection. In Italy, two working lines were developed. One coordinated by Rete Semi Rurali, based on a beef-heart tomato population, created from SOLIBAM FP7 project, by crossing four local varieties selected for organic cultivation. This dynamic heterogeneous population was evaluated and bred in four different locations along the country: Emilia Romagna, Campobasso (Molise), Castronuovo SA (Basilicata) and ALSIA research station in Basilicata. 400 plants were grown on each location and participatory selections was performed with farmers invited to open field days. A second participatory initiative was coordinated by CREA-Monsanpolo, where an experimental MAGIC population (Multiparent Advanced Generation InterCross) under construction was evaluated for agronomic traits in successive selfing generations following a participatory approach in different Italian pedo-climatic conditions.

A considerable amount of results have been compiled from the three initiatives. Despite many of them are still being processed, several findings can be showed and discussed. The participatory initiatives have strengthened the links between farmers and breeders in all the cases and also enable a more efficient selection based on a wider vision of the traits of interest and plant agronomic performance. In addition, the initiative in Spain has enabled to widen the network to consumers, who are the end users of the product and, as a result, they play an essential role in the preservation of agrodiversity. Thus, when possible, consumers must be involved in participatory breeding in terms of taste preferences as well as to make them aware of the importance of preserving agrodiversity by being part of local networks.

Also, in the three initiatives a remarkable diversity has been found in terms of agronomic traits (plant development and management, fruit appearance, incidence of diseases), intervarietal in the collections evaluated in Spain, intravarietal in the dynamic populations of RSR and both in the MAGIC from CREA. In all cases, such diversity has enabled the selection of varieties and populations adapted specifically to the organic cultivation of different pedo-climatic conditions. This is important in the frame of the new European organic farming regulation on Organic Heterogeneous Materials (2018/848/EU).

The analytics and taste panels with consumers have revealed a remarkable varietal diversity in the content of sugars, acids and bioactive compounds, as well as in the profile of volatiles, which is being related with the preferences of consumers (e.g. young consumers prefer sweeter tomatoes, while adults usually prefer balanced combinations of high sugars and acids). Also, some major volatiles have contributed in a positive way to consumers preferences (e.g. high terpenoids, low grassy/herbaceous compounds).

The results and lessons learned in these initiatives will inspire organic breeders and small farmers devoted to diversification of organic seeds.

Aknowledgements

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GENOME-ENABLED, FARMER-PARTICIPATORY SELECTION: MAKING EDGES MEET

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Keywords: genomic selection, participatory plant breeding, *Pisum sativum*

Genomic selection and farmer-participatory selection are frequently seen as contrasting selection strategies. The former is getting pivotal for corporate and trait-based breeding, whereas the latter is a key component of community-based breeding. A previous study focusing on field pea (*Pisum sativum*) for organic systems of Italy showed that (i) breeders and farmers do not agree completely on priority traits to select for, (ii) farmers' selection outperformed breeders' selection in terms of grain yield and acceptability by farmers of new selections, (iii) a simple farmer acceptability score was about as efficient as grain yield-based selection in terms of yield gains in independent environments, and (iv) the farmer acceptability score could be predicted with high accuracy by a genomic model based on SNP markers issued from genotyping-by-sequencing (GBS) (Annicchiarico et al., 2019). Farmer acceptability as predicted by the genomic model could be valuable whenever farmers' selection was difficult, such as in the presence of large sets of test lines and/or in early selection stages. The objectives of this study were (i) to verify the ability of genomically-modelled farmer acceptability to predict the actual farmer acceptability and the grain yield of different pea lines and test environments, and (ii) to compare yield-based selection, selection based on the acceptability score assigned by farmers, and selection based on the genomically-predicted farmer acceptability score, in terms of yield gains of selected lines in a following cropping season. The study was based on grain yield and farmer acceptability score values of 144 pea lines issued by six crosses among elite cultivars, which underwent GBS molecular characterization and field evaluation in the seasons 2018-19 and 2019-20 in Lodi (Northern Italy).

Acknowledgement

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A NETWORK APPROACH FOR LARGE-SCALE PARTICIPATORY VARIETY-BY-CONTEXT TESTING: RESULTS FROM SORGHUM VARIETY TRIALS IN MALI

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Keywords: farmer-breeder network, gender, seed

Smallholder farmers in Mali seek options to increase their sorghum yields in order to improve food security and income. The identification of which ‘improved’ open-pollinated (OPV) or hybrid variety out yield smallholder farmers’ own local varieties under their diverse, predominantly low-input, production conditions is challenging. Furthermore, understanding whether yield advantages are shown under the farmer’s own- or improved-agronomic practices, and in men’s- or women’s-fields (with even lower soil-fertility) is needed to make informed decisions. A network of famer cooperatives engaged with public breeding programs in participatory breeding of new sorghum varieties seeks to address this challenge. One question posed by the network was “What yield advantages can men- and women-farmers expect from recently developed OPV and hybrid varieties relative to their own local varieties?

Our objectives are to a) describe the approach taken by this ‘Sorghum Network” for joint learning through large-scale, farmer-managed, variety testing under alternative agronomic-practices, and b) use farmers’ test results to examine what technologies (type of variety and agronomic practice) currently offer women and men farmers opportunities to increase their sorghum yields.

The famer-managed variety trials, locally called ‘Adaptation Trials’, are conducted to give a much larger number of farmers the opportunity to evaluate new experimental varieties under their own field conditions. Participating farmers chose the varieties to be tested from first-stage participatory trials conducted at limited sites with greater researcher involvement. Farmers had the option to plant three- or five-entry single-replicate trials with one local variety and two- or four experimental varieties chosen by the respective cooperative. Women farmers chose to conduct either three- or five-entry trials whereas all men preferred conducting five-entry trials. Based on farmers' suggestions, each variety plot was split in half with their normal agronomic practice (without fertilizer) applied to one half and an improved practice to the other half. All cooperatives chose to apply fertilizer (100kg/ha DAP and 50kg/ha urea) for the improved practice, and some also increased the planting density.

Yield results of two consecutive years from 188 farmer trials (83 women) which included all three variety types (local- bred-OPV and hybrid) were analysed. These trials, conducted by 34 farmer cooperatives, covered the three major sorghum production zones in Mali. A total of 50 varieties were tested, including 19 OPV and 8 hybrid test-varieties, all bred with predominantly local-germplasm, and 23 local varieties.

Combined analysis over all 188 trials revealed highly significant yield differences between the three variety types and between the two management practices. However, the interaction between variety type and management practice was non-significant. The hybrid-variety group exhibited much higher yields than the local varieties in women's trials (1417 vs 1065kg/ha, respectively) and men's trials (1089 vs 837 kg/ha, respectively) averaged over both management practices, with relative hybrid superiorities being similar for women (33%) and men (30%). Looking within management practices revealed hybrid superiorities to be higher with farmer-management for women (39% vs 31% with improved practice) but lower for men (22% vs 37% with improved practice). Whereas the OPV variety group showed yield advantages over the local varieties in zones close to where they were bred, they showed inferiority in the more distant zone (Koutiala). The fact that many women obtained higher mean yields than men may be due to women's greater enthusiasm and care for their variety trials.

Plot-to-plot yield comparisons between hybrid and local varieties in individual farmers' trials suggest that the risk of newly developed hybrid varieties yielding less than the farmer's local variety (reductions of 125kg/ha or more) may be somewhat higher for women (25% of comparisons) than men (12% to 15%) under both management practices. Developing and maintaining a diversity of varieties types, including hybrids, new OPV and local varieties appears necessary to meet the needs of diverse men and women farmers.

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A POSTGRADUATE COURSE ON PARTICIPATORY PLANT BREEDING AND RESILIENT SEED SYSTEMS: COLLABORATIVE DESIGN, IMPLEMENTATION, AND RESULTING EXPERIENCES

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Keywords: participatory plant breeding, seed systems, seed policies, value chain actors, training

Participatory plant breeding (PPB) and resilient seed systems (RSS) can play a central role in promoting sustainable food systems (i.e. diverse, robust, healthy, and equitable). Developing and strengthening PPB and RSS offers vital entry points for responding to global challenges ranging from climate change to promoting agricultural-biodiversity and sustainable development. Despite this promise, exposure to-, critical thinking about and training in participatory breeding and seed system concepts, issues and approaches is insufficient to support professionals and graduate students who seek to contribute to resilient seed system development. Establishing such programmes, in regular academic- and other fora, was identified to be a top priority by the Shared Action Framework for Resilient Seed Systems of the Global Alliance of the Future of Food (GAFF 2020).

An alliance of diverse programs and practitioners collaborated to design and implement a postgraduate course that addresses PPB and RSS issues and opportunities in the Global South and North. The purpose of this paper is to highlight key aspects of the course design and explore the experiences and insights gained by the first participants and trainers of this course, in order to contribute to and support similar initiatives in the future.

The course content addressed five topic areas: i) Decentralised and participatory approaches to plant breeding and seed system development; ii) Governance and policy issues regarding seed control, (co-)ownership and benefit sharing; iii) Specific needs and challenges for different crop types and socio-economic contexts; iv) Approaches for multi-actor collaborative learning; and v) Interactions and trade-offs between technical solutions and social choices. Learning goals were set for each key topic area. For example, learning goals included gaining understanding and insights into organizing farmer-breeder collaboration, approaches, tools and concrete cases of joint learning by diverse crop value-chain actors, and the consequences of alternative regulatory and policy approaches for PPB and RSS in different contexts and countries.

Key elements of the course design included a) invited lectures by practitioners for each thematic area, based on their engagement in different geographic and disciplinary contexts, b) follow-up discussion (dedicating equal time to lecture and discussion), c) small-team group work to identify key opportunities and prepare proposals to address a concrete issue, and d) presentation and discussion of group projects. The course organizers requested each lecturer to share one publication relevant to their topic. Course participants were invited to read these publications and prepare questions prior to each topics' presentation.

Both participant feedback and reflections by the course organizers are presented. The advantages and disadvantages of format (on-line vs. in presence), mode of organizing the small group project-work and lecturer's engagement with these groups, options to include farmers- and other-presenters, and balance between addressing concepts vs. practical experiences and tools are discussed. We reflect on need and possibilities of design and implementation of similar courses in other contexts. The course materials are available at Organic E-prints (https://orgprints.org/38731/).

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PARTICIPATORY POTATO BREEDING IN THE NETHERLANDS: THE BIOIMPULS PROJECT

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Keywords: potato, participatory breeding, *Phytophthora* resistance

To facilitate and further stimulate organic potato production in the Netherlands new varieties resistant to late blight are bred in cooperation between researchers from WUR and LBI together with farmer breeders and professional breeding companies.

Breeding capacity amongst organic potato farmers is to be increased by setting up a dedicated training course.

Together with farmer breeders and professional breeding stations resistance genes originating from wild *Solanum* species are incorporated in selection material which is selected in a participative way.

A crossing program is carried out by WUR in which 11 major resistance genes conferring resistance to *Phytophthora infestans* are used. Pre-breeding to introgress the major resistance genes into near commercial potato clones is carried out entirely by WUR, while seeds from crosses that reach the commercial level are mainly distributed over farmer breeders and breeding companies to select resistant clones showing commercial potential.

All selections from farmer breeders, breeding stations and WUR are subsequently together evaluated for resistance, yield potential and general agricultural performance both under organic and non-organic management. When applicable, presence of resistance genes is confirmed with molecular markers.

Selected clones from commercial crosses are both reused by the project as input for further breeding cycles, and after further commercial evaluation brought to the market by one of the breeding companies.

To increase breeding capacity amongst organic potato farmers a dedicated potato breeding training course is developed addressing topics like basic potato genetics, designing an conducting crosses, raising seedlings, designing selection trials, selection procedures and regulatory issues.

In Bioimpuls-I (2009-2014) and Bioimpuls-II (2015-2019) 7 breeding companies and 14 farmer breeders were engaged at some stage.

Since the start in 2009, 521,810 botanical seeds were distributed, of which 499,838 at the commercial level and 21,972 at the pre-breeding level. In total 399 new selections by farmer breeders and breeding stations were evaluated centrally for *Phytophthora resistance* and agronomic potential. The first selection derived from Bioimpuls crosses is submitted for official variety registration and National listing in 2019, expected to be registered early 2022.

The practical training course for small scale potato breeding has trained 208 people with backgrounds in organic farming, professional breeding, education, and seed certification.

Bioimpuls has received funding for the next 10 years and will run until 2029, at which stage all resistance genes processed will be incorporated in commercial selection pipelines, from which new *Phytophthora resistant* varieties will become available for organic and low input potato production in the Netherlands and beyond.

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PARTICIPATORY RESEARCH INTO THE QUALITY OF VEGETABLES IN ORGANIC FARMING

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Keywords: participatory research, quality, organic farming

Organic farming has grown rapidly over the last years and consumer demand for organic products is increasing. Especially during the COVID-19 outbreak organic farmers in the Netherlands observed an increase in sales in both their local shops and in the number of online customers. The major reason consumers increasingly favor organic over conventional food products is the belief that organic food offers a healthier alternative or it has a higher nutritional content.

For organic agriculture it is important to guarantee a high food quality as it is one of the main distinguishers in relation to conventionally produces food products. It is often difficult for an organic grower, organic retail store or a restaurant to know which varieties taste the best and are the healthiest. In addition, the method of cultivation, soil type, irrigation regime, etc. is varied, making it difficult for a grower to select the right variety that provides the grower with the best results.

A number of participatory studies are being conducted by the Louis Bolk Institute, among several organic producers. These studies examine the quality of pumpkin and beetroot. Five varieties of each crop are monitored on different organic farms for 4 years. Every year, these varieties are harvested and analysed for different aspects. This mainly concerns health characteristics such as sugar content, dry matter content, nutrients and taste, but also for other (cultivation-related) characteristics, such as yield, uniformity and weight of the products. In addition the shelf life of the different varieties and crops is examined.

Several times per year, the results are discussed with all participating parties (farmers, students, organic stores, restaurants and chefs). In addition, taste tests are organized and visits are made to the various organic farms.

The trials will run until 2021. Until now, highly significant differences have been found for taste and nutrient contents between growers. Soil and cultivation method (for example irrigation) seem to have the greatest impact on how tasty and healthy a product is. In addition, smaller significant variety differences are found per grower. The most suitable variety for one grower it not always the most suitable variety for another grower.

The outcomes of these trials provide valuable, previously lacking information to organic growers.

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BEYOND THE YIELD DRIVEN STRATEGY: BREEDING FOR SPECIFIC ADAPTATION IN ORGANIC RICE IN ITALY

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Keywords: organic agriculture, biodiversity, participatory plant breeding, heterogeneous material, farmers' knowledge, rice

Italy is the largest producer of rice in Europe. The production is mainly located in the intensive agricultural areas of the Po Valley, which are also among the most fertile areas of Italy. In these areas, agriculture is based mainly on monocultures and intensive exploitation of land, together with a widespread use of chemical inputs and water. However, during the last decades organic rice production has increased, often lead out by the self-organization and cooperation among a number of pioneers' farmers. The implementation of a new rice breeding strategy, specifically targeted to the organic rice farming systems (ORFS), represents a necessary and urgent contribution to this transition.

This paper describes a set of farmer-led innovations, ranging from agronomic practices for ORFS management to participatory breeding (PPB). The activities involved a multi-actor network in participatory selection of locally adapted varieties suitable to the agro-ecological practices of each farm hosting the field trials. The main objective of this research is to address the most urgent critical issues in ORFS such as water scarcity, soil salinization, climate-driven presence of novel aggressive weeds, the coexistence with many animals in wet habitat and the emission of greenhouse gases (GHG).

In 2019 four organic and biodynamic rice farms hosted on-farm trials for the evaluation of 17 local rice varieties (released before 1960) with the aim of identifying those most suitable for ORFS. The experiment was set up as an incomplete randomized trial divided among four farms, each adopting different ORFS management practices. The fields were prepared following the prevalent weed control management practices in the region: i) rice dry sowing at different depths (6 cm or 3 cm), followed by dry conditions combined with different intensity of mechanical weeding (two or four comb harrow passages); ii) sowing over green mulch obtained from different cover crops, followed by flooding. The trial was repeated in 2019 and 2020, using a partially replicated design with plots size of 6 m², 16 unreplicated varieties and 6 varieties replicated 4 times. The resulting 40 plots were arranged in 4 rows and 10 columns. A number of phenotypic traits were collected ranging from ear height to plant height, stem posture, tillering and susceptibility to *Fusarium spp* and *Pyricularia oryzae*. The participatory evaluation involved more than 120 farmers, technicians and researchers who scored each plot from 1 (worst) to 5 (best). The data were submitted to spatial analysis, ANOVA and PCA (GGE Biplot) with GenStat v 20 and R software.

Preliminary results indicate that for most phenotypic traits there are significant differences not only between accessions but also within the same accessions among the farms hosting the trials. The interaction between "farms x varieties x field management" was significant for "height" and "ear length", as well as "disease tolerance" and "weed suppression", two traits that are relevant for ORFS management. The results allowed the identification of some promising agronomic/varietal combinations that can increase yields and yield stability over time. This emphasises the importance of specific adaptation for rice cultivars, although farmers' knowledge of their agro-ecosystems remain pivotal for successful ORFS management. The application of a decentralized and participatory selection model within a community of practices that have long been deploying organic rice management techniques is the prerequisite to define a new breeding strategy tailored to site-specific needs. Our research shows that the heterogeneity of organic rice growing systems cannot be addressed with a linear agronomic approach, nor can a centralized breeding programme and a centralized seed system provide the diversity of locally adapted cultivars needed to exploit the full potential of ORFS.

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AMBASSADORS OF BIODIVERSITY: A PARTICIPATORY PROJECT TO VALORIZE TRADITIONAL SEEDS

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Keywords: agrobiodiversity, genetic resources, landraces, seed bank, vegetables

"Ambassadors of Biodiversity" is a project of citizen science, which involves both growers and educational communities, who have a key role in this research, growing traditional seeds and collecting accurate data.

The objectives of this research were (1) to improve the quality of the information associated with some accessions stored at the Vegetable Germplasm Bank of the CITA-Aragón Spanish Research Center (BGHZ-CITA), making the collection more valuable, and (2) to involve citizens in biodiversity research, raising awareness in society, especially younger generations, of the importance of conserving and using plant genetic resources.

To reach these objectives two networks of "Ambassadors of Seeds" were established.

One network of "Ambassadors of Seeds" was formed by traditional non-professional growers from different localities of the Aragon region. These volunteers grew some traditional seeds collected years ago from their villages and preserves in the seed bank BGHZ-CITA. Many of the varieties are no longer cultivated, so the local growers had the opportunity to recover the seeds, transmit their knowledge, and collaborate in the research that will help their conservation and sustainable use.

A total of 104 vegetable landraces belonging to 12 crops were distributed among the network of growers formed by 43 people, as follows: tomato (41 accessions, henceforth ac.), pepper (14 ac.), melon (10 ac.), lettuce (10 ac.), onion (9 ac.), pea (7 ac.), broad bean (5 ac.), bean (5 ac.), chard (2 ac.), spinach (1 ac.), cucumber (1 ac.) and lentil (1 ac.).

The second network of "Ambassadors of Seeds" was formed by the educational community, including teachers and students, who grew the traditional seeds in their scholar orchards.

In this case, only two leguminous crops were grown: broad beans (*Vicia faba* L.) and "bisaltos", a variety of pea (*Pisum sativum* L.) whose green pods are very appreciated and traditionally consumed as a vegetable in the region. The reason was that both crops develop the whole growing cycle during the school year. To show how to take the data a Teaching Guide available online was developed according to the different educational levels of the students. The Guide for teachers explains the descriptors that have to be recorded, which are mainly based on the Bioversity International descriptors. The idea is that the students recorded the data in a similar way to the primary characterization is done in the seed bank, but according to their knowledge and available media. In that way, the students collected accurate data and processed the information for the project. In addition to aspects directly related to agriculture, agro-environmental education topics have been incorporated into the project to promote attitudes and values towards the environment and advertise the relevance of biodiversity conservation for the future.

A total of 59 seed samples belonging to 30 different accessions of the two crops were distributed among the network of the educational community formed by 31 school centers, as follows: 14 of broad beans and 16 of "bisaltos", which were selected according to the scholar orchard location.

Since the project began in September 2019, it started as originally planned, but the health crisis due to the pandemic affected some of the programmed activities. Nevertheless, despite everything we got valuable information associated with the accessions of the seed bank collection that has improved the value and utility of this agrobiodiversity. Besides, some of the studied varieties will be grown again in their original regions, since several growers have produced their own seeds from the local varieties provided by the BGHZ seed bank for growing next year. For their part, the students and the large number of people who attended the dissemination and training activities became aware of the importance of conserving biodiversity for future generations.

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THE PROMISE OF COMMONS FOR THE ORGANIC BREEDING SECTOR: CONCEPTUALIZING SEED COMMONS

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Keywords: Seed Commons, conceptualization, organic breeding, governance, food sovereignty

'Commons', defined as institutions that enable the collective development, management, and sharing of goods and resources, are an alternative principle of resource management. It carries the potential for a more sustainable use of natural resources, a democratization of resource governance, and for opening up experimental spaces beyond increasing economization and privatization of resources. Commons in the fields of seeds and varieties are discussed as approaches that enhance food sovereignty, farmer empowerment, and sustainable agriculture.

Commons approaches in the seed sector are multi-faceted: They span from traditional seed systems, such as seed sharing networks, to recent anti-enclosure movements that resist intellectual property rights on varieties, like organic breeding initiatives. In practice, Commons principles are already realized in the field of organic vegetable, grain, and fruit breeding. We provide condensed insights into the research results of the projects RightSeeds and EGON on conceptualizing Seed Commons, based on inter- and transdisciplinary research approaches. Depicted insights build on the publications by Sievers-Glotzbach et al. (2020) and Wolter & Sievers-Glotzbach (2019).

For conceptualizing Seed Commons, we combined a literature review, in-depth analysis of case studies as well as discussions at transdisciplinary project workshops and an international scientific workshop. We identified four criteria that characterize diverse Seed Commons arrangements at local and regional scales: (1) collective responsibility for the protection, provision, and development of seeds and crop diversity; (2) protection of seeds from private enclosure, such as plant variety protection and patents, as well as bio-technical methods that limit seed saving, exchange, and use by farmers; (3) collective, polycentric management in decentralized network structures; and (4) sharing of scientific knowledge as well as practical knowledge and skills.

We illustrate these criteria by the example of two commons-based breeding organizations in Germany: (a) the organic vegetable breeding initiative Kultursaat e.V., and (b) the organic fruit breeding initiative apfel:gut e.V. For Kultursaat, ten qualitative, semi-structured in-depth interviews with breeders and coordinators were carried out in 2018. To gain insights for the analysis of apfel:gut, we used three sources of data: a qualitative interview with two leading members , relevant formal documents of the organization, and a focus group interviews with the members of apfel:gut in 2018.

Our criteria of Seed Commons point to general sustainability potentials, which can help to highlight the importance of those initiatives for achieving two core sustainability objectives. First, elements of food sovereignty are fostered. The protection of seeds from private enclosure guarantees farmers access to seeds, and the sharing of practical skills and formal breeding knowledge provides associated knowledge. Second, Seed Commons support social-ecological resilience of agricultural systems. Actors in those Commons express and practically take responsibility for the protection, provision, and development of crop diversity using forms of collective governance.

To conclude, commons-based breeding presents a promising approach specifically for the organic breeding sector to develop innovative strategies for enhancing agrobiodiversity and food sovereignty. It credibly realizes the principles of organic agriculture, including issues of intellectual property rights, process transparency, and participatory breeding approaches.

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LANDSORTEN – A SEED SYSTEM WITHOUT SEED COMPANY

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Keywords: seed production, financing plant breeding

Farmers have an interest in high quality seed at a low price, whereas seed companies have an interest in high prices and low production costs. To control this contradicting economic interest, EU and many other countries and unions have implemented seed regulations, setting strict standard for marketing of seed, including approval of varieties legal to put on the market. The EU legal framework has let to high costs for introduction of new varieties onto the market, resulting in lack of diversity of varieties with limited market potential, including varieties aimed for organic farming conditions. Even though organic farming has a well defined demand of cereal varieties with certain specific traits such as good weed competition, resistance to certain diseases and ability to meet baking quality standards under low input conditions, few if any plant breeders are able to establish a profitable business to meet this demand.

Most plant breeders and seed companies are owned by companies and consortia with a main income generated by either production or marketing of agrochemicals. The supply of seed to organic farming from such companies therefore jeopardize the integrity of organic farming.

The EU seed directives are marketing regulations. They do not regulate the plant breeding of adapted varieties for organic farming, and does not regulate the USE of such varieties by organic farmers. It only regulates the marketing of seed from the plant breeder to the farmer.

LANDSORTEN is a membership organisation under establishment with the aim to solve the problem of supply of adapted cereal varieties for organic farming. The organisation takes advantage of the fact that the EU seed directives only regulates the marketing of seed. LANDSORTEN is not a seed company producing and marketing seed. Instead, seed is only transferred from the plant breeder to the farmer on a trial basis in limited quantities. The EU Directive states in Article 3 that “Member States may provide for derogations … for research and trials...” (Council Directive 66/402/EEC). Different member states have implemented this article in different way. In Denmark, the implemented wording in §30 in the executive order (BEK nr 1014 af 26/06/2020) that “*the requirement for certification does not apply for seed….. in small quantities on the purpose of trials, scientific research or breeding*” (authors translation). It is therefore perfectly legal for a plant breeder or for LANDSORTEN to sell seed to a farmer on the purpose for the farmer to try if the variety fits his requirements. The term “small quantities” is not well defined, but of course the quantity must be large enough to fit the purpose of the trial production. With modern sowing and harvest equipment, this means at least some hundred kg of seed. If the trial production is successful, the farmer can legally reproduce the seed as home saved seed, as home saving of seed does not involve marketing of seed, and therefore is not regulated by the directive.

LANDSORTEN is established by Agrologica as a plant breeder, and Gl. Buurholt Hovedgård being a company specialised in facilitating farmers in production of home saved seed, driving from farm to farm with seed cleaning equipment.

To finance the expenses for plant breeding, Agrologica is paid by LANDSORTEN, and LANDSORTEN charges a membership fee from the farmers based on the area grown with varieties from LANDSORTEN. As such, the system works without seed being sold except for the initial seed for a trial production. Farmers pay a fee for the membership, and the fee covers the expense of a seed sample of 200kg seed for a trial production. The seed can come from Agrologica or from farmers growing the varieties from LANDSORTEN, and Gl. Buurholt Hovedgård guarantee the seed quality. The seed is given with a restricted right to reproduce home saved seed as long as a membership fee is paid to LANDSORTEN.

Initially, LANDSORTEN acts with organic millers and farmers supplying grain to these mills, supplying varieties and heterogeneous material with high baking quality, but is open also for other farmers including livestock farmers requesting grain for feed.

The limitation and disadvantage of the system is that farmers need to set aside land for seed production resulting in reduced net-production, and need to plan changes in varieties choice and crops one year in advance in order to be able to produce their own seed. The system is only designed for seed crops like cereals and pulses, whereas vegetables and other crops need other systems to cope with the challenges of the current seed system.

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DESIGNING VARIETAL EVALUATION SYSTEMS FOR ORGANIC FARMING: A MULTI-ACTOR APPROACH

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Keywords: varietal assessment, organic farming, consultation, participatory

In a context of a significant development of organic farming (OF), the demand for varieties adapted to OF is increasing. To develop the supply, it is necessary to acquire varietal assessment tools adapted to OF, whether for breeding, for registration in the Catalogue or simply to provide reliable references to users. This condensed article gives an overview from the perspective of stakeholder collaboration on varietal evaluation systems for OF. It is mainly based on current reflection within GEVES and on analysis of results from the research programme ECoVAB (Fontaine *et al*, in press), which investigated for arable crops how to describe and evaluate a variety adapted to OF.

Several topics have been explored in ECoVAB. 1/ The expectations in terms of varieties of farmers and collectors in the organic sector were surveyed and compared with the current variety supply. 2/ Varietal results for soybean and wheat, acquired in OF and conventional farming (CF), were compared to assess their redundancy, complementarity, or specificity. 3/ Varietal response to limiting factors commonly encountered in OF was analysed: water stress for soybean; nitrogen stress for wheat. 4/ The suitability of varieties to intercropping has been studied in the case of wheat-legumes mixtures, by questioning whether the behavior of a variety grown in sole crop is predictive of its behavior in mixture. Finally, proposals have been made to design evaluation systems for varieties intended for organic farming.

The results confirm that 1/ the assessment of specific traits is expected in OF. In particular, the ability to compete with weeds, based on various criteria. Describing the canopy architecture and its dynamic development is also of interest for predicting behaviour in intercropping or in variety mixture. 2/ More generally, if the need for assessment in OF conditions is emphasised by organic users, this can be modulated: not all varietal traits need to be evaluated in this cropping management system. Indeed, there is a complementarity between varietal evaluation in OF and CF, which depends on the crop species, the criteria considered, the genotypes tested and the test conditions (level of input use, pedoclimate…), questioning the relevance of mixed systems. 3/ In view of the diversity of growing conditions (probably more prevalent in OF because there is no possibility of adjusting through the use of chemical inputs), there is an interest in exploring variety ranges for diverse environments, rather than looking for a single ideotype. 4/ For some traits for pea (height at the end of cycle, yield), the values in sole crop did not seem to be predictive of those observed in mixture. Consequently, a specific evaluation of these traits in intercropping appears necessary (cf Moutier *et al*., "Breeding for diversity" topic).

In view of these results and in relation to the involvement of actors, it appears that previous consultation is necessary between stakeholders (from farmers to consumers), advisors, researchers and breeders, to define which varieties are sought for OF. Consultation should participate to design the varietal evaluation systems by focusing on the expected qualities, and their translation into traits; on the growing conditions and their potential variability; on the possibility of extrapolating available data from CF or setting up tests in CF.

Although some results can be provided by data obtained in CF, collectors and farmers in surveys cite the importance of setting up varietal assessment platforms in OF, whatever the crop species. Those platforms are in fact privileged discussion forums where everyone can visually appreciate the varieties and share their experience. However, this raises questions about the type of such varietal platforms, given that they can be imagined at different levels, modulating (i) the implication of researchers and farmers (notably for notation), (ii) the trial location on a station or on-farm, (iii) the trial design (large band or small-plots with replication, protocols). Studies bringing together statisticians, practitioners and variety specialists would be useful to design new participatory evaluation systems combining these different types of trials and integrating farmers' references and knowledge in the assessment of varieties. In addition to the description of varieties, targeted communication on OF was clearly expected.

From breeding and variety registration phases to post-registration assessment, this requires a good coordination between research and development stakeholders, i.e. the implementation of dedicated consultation groups, institutional or not, questioning the level of participation, either consultative or collaborative (Probst *et al*, 2003). This is consistent with the results of surveys showing that farmers are key actors with whom to collaborate, in addition to stakeholders in commodity chain, to establish knowledge needs on varieties and to guide breeders and assessors. It is necessary to continue to identify these needs at regular intervals of time, by comparing them with the available variety supply and the needs of the commodity chains, whether short or long.

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ON-FARM COMPARISON OF TRIALS BASED ON DIFFERENT PLOT SIZES TO HELP FARMERS' WHEAT CULTIVAR CHOICE

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Keywords: organic variety tests, wheat, yield, quality, NIR

All farmers are searching for the best performing plant cultivars to improve their profitability, but there is still a lack of knowledge on how to choose these cultivars for organic production in Hungary. Organic cultivation is more affected by environmental factors compared to conventional due to the ban on artificial pesticides, herbicides and fertilizers. Additionally, without an official organic small plot variety testing system, there is a strong limitation regarding the annual number of cultivars that could be tested under on-farm growing conditions and cultivated with farm-sized machinery. To overcome this obstacle, the equivalent of an on-station trial (with replicated small plots) was applied in the field of an organic farmer in Nagydorog, Hungary between 2019 and 2020. The small sized plots (6 m² each) were placed next to the farmer's larger plots (1000 m² each) using the same set of winter wheat cultivars (2019: 8 cultivars, 2020: 7 cultivars). Grain yield, protein and gluten contents, and Zeleny sedimentation index were measured in three replications both in the small plot trial (set up according to randomised complete block design) and in the farmer's strip trial, where samples were analysed from three representative 1 m² plots.

Regression analyses carried out for each trait resulted in significant moderate correlations between the values of the two trial types regarding all three grain quality traits: protein content ($R^2=0.56$, $p<0.001$), gluten content ($R^2=0.45$, $p<0.001$) and Zeleny index ($R^2=0.47$, $p<0.001$). However, the grain yield of cultivars harvested from the two plot types resulted in the lower threshold of the "strong" correlation interval ($R^2=0.60$, $p<0.001$). The strength of these significant correlations were increased up to $R^2=0.7$ in the case of protein and gluten contents when only those cultivars were analysed which were tested in both years, while the trial types showed significant correlations around $R^2=0.55$ regarding the same set of cultivars for the other traits. The correlation between the two trial types for the quality traits of all varieties were even stronger ($R^2>0.9$ for protein and gluten contents, $R^2>0.7$ for Zeleny index), when only year 2019 was evaluated.

In two-year average, grain yield and gluten content were 27.3(±10.3)% and 9.9(±7.9)% higher, respectively, in the small plot trial than in the samples collected from the farmer's plots, while Zeleny index was 33.2 (±28.5)% higher in the farmer's samples. As the trials were carried out under similar growing circumstances, these differences in quality traits (especially in Zeleny) were most likely the effect of the prediction calculated by spectroscopic technique (NIR). In this regard, the results also showed that the quality measurement with NIR technology is reliable (at least in a relative sense) only in the case of protein content, because there was very little difference (0.9±5.2%) between the two trial types.

This high reliability was also demonstrated by the very close similarity in the rank of the varieties tested for the two years: the better performing half of the cultivars had the same rank of protein content in the two trial types. Regarding gluten content, only the best and the worst cultivars were the same in the two trial types in both years, while only the best cultivars were the same for Zeleny index. Considering the very strong rank correlation between the protein and gluten content ($R^2>0.81$) or between protein content and Zeleny index ($R^2>0.83$) of the varieties in all year-trial type combinations, strict positive selection can be used to decrease the number of varieties in each year ending up in a few desired varieties that will produce high quality in the given farming environment.

Based on these results, the effectiveness of the farmer's wheat cultivar choice can be increased by implementing a combination of the small plot and large plot trials on the targeted farm. The small plot trial can be recommended for testing high number of varieties (including quality controls) under the targeted growing conditions using high throughput NIR measurement, while for grain yield, a negative selection can be made in the same trial. Two years of testing in replicated small plots could result in a relatively reliable assortment of a few varieties which could be put in the on-farm yield trial for one year in order to define the final rank of the selected varieties for the given organic farm.

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INTRODUCTION OF PARTICIPATORY BREEDING PRACTICES IN HUNGARY – A CASE STUDY

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Keywords: durum wheat, EPO, organic heterogenous materials, participatory breeding, participatory research

The traditional act of plant breeding was very different from modern breeding. It used to be done by farmers themselves for thousands of years; on their land, under their management, soil and climatic conditions. The basis for this was the heterogeneity of the plant materials used and the purposeful selection made by farmers. Although this process was once widespread, it has almost disappeared and it needs to be reintroduced, improved by modern knowledges and shared with farmers again. The reason for this is the recognition that heterogenous materials can potentially adapt dynamically to their cultivation sites under the changing climatic conditions and the increasing threat of pathogens. They can eventually be more resilient, produce more stably than genetically uniform varieties, especially under the more challenging cultivation systems, such as organic farming. The EU regulations on organic production are changing and will enter into force by 2022, creating more freedom for farmers and seed producers regarding the methods and plant materials they use for breeding and crop production. This also means that organic farmers will be allowed to market seeds of their own cultivars bred by themselves according to their local preferences and needs.

The start in Hungary – 2017/18

The evolutionary evolving durum population (EPO), received in the frame of the EU Horizon 2020 project SolACE from INRAE, has been tested and propagated since the autumn of 2017 in Martonvásár, Hungary, and has also been adapting to our climate since.

Directions of activities in crop year 2018/19

Bulk propagation of the segregating EPO population remained the most important viewpoint in 2018/2019, but targeted manual selection of spikes also took place. The two sub-populations, created in the first growing season via part of the original sowing seed lot sown in winter and part sown in the spring, were maintained accordingly. On arrival of a new shipment of a larger amount of sowing seeds from EPO propagated in Italy in 2017/2018, the on-farm experimentation could also begin on one site, in Füzesgyarmat (FGY).

From 2019/20 up till now

Propagated to a sufficient amount, the EPO population of Martonvásár (MV), together with the propagated FGY population were ready for on-farm testing, which started in 2019. The organic trials took place in Nyíregyháza, Bugac, FGY, Želiezovce (Slovakia), while those in conventional were in Kiszombor and Vlčany (Slovakia). The rising interest of farmers made a wider-range of on-farm trials possible, starting in 2020/2021, in the frame of a new Hungarian research project (MNVH). More than a dozen new farmers joined the initiative from all over Hungary with the intention of learning participatory breeding methods.

Evolutionary processes - driving forces of natural selection

Though adaptation to various soil and climatic conditions is often not a spectacular process, it can also lead to powerful evolutionary processes driven by natural selection. Such examples were observed under the sandy and weedy conditions of Nyíregyháza and in Bugac, where the drift-sand combined with extreme drought caused a dramatic loss of plants. The countrywide epidemy of *Fusarium* in 2019 led also to an immense loss of susceptible plant individuals, the grains of which were not present in the next generation.

Spike selection – the participatory breeding approach

Starting in MV and continuing from the following years in Želiezovce, FGY and Bugac, a positive selection of the best, sightly-healthy spikes was carried out to create new local population lines. Mass counter selection of hyper-tall plants (via cutting off their spikes) was performed by the farmer of FGY.

Plans and conclusions

Seeds of all local EPO populations collected from all sites were sown in the autumn of 2020 on small plots in Szár (Hungary), a location with relatively neutral conditions. This will allow comparisons between population variants regarding phenology, morphology and yield characteristics. It also provides an opportunity for extensive genetic analyses aiming at disease or abiotic stress resistance but also at assessing the adaptation potential of EPO population or the degree of genetic change or a drift in case it had taken place.

The introduction of interested farmers to participatory breeding methods will be continued through a practical workshop (planned for June 2021) and by publishing a booklet on participatory breeding methods and good practices of sowing-seed saving. The participating farmers are not only open-minded but also more conscious; they want to be less dependent on external resources, whilst producing their own healthy food. Some of them even have very practical aspects in mind, such as finding commercial gaps – producing “niche”-products with their own EPO population.

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MAIZE PARTICIPATORY BREEDING IN PORTUGAL – GERMPLASM EVALUATION

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Keywords: participatory breeding, maize, HUNTERS, landraces

The Participatory Plant Breeding Program "VASO" (Sousa Valley in Portugal) started in the 80s with the purpose of valorising the maize landraces for farmers needs that included the use of maize for maize bread.

Phenotypic and yield evaluations using HUNTERS descriptor (Plant **H**eight, **U**niformity, **L**eaf angle, **T**assel, **E**ar placement, **R**oot and **S**talk lodging) were conducted using 10 maize landraces (8 populations and 1 composite cross population (CCP) derived from PPB "VASO", and 1 CCP derived from 40 maize populations from Azores, Portugal that were obtained in a collected mission in 1979) (Bettencourt and Gusmão, 1982; Mendes-Moreira et al, 2017).

The trials followed the randomized complete block design with three replications in 2 locations distance 15 km in Sousa Valley region (Macieira de Lixa and Lousada – agroecological sites). Aiming to compare the agronomic behavior and adaptation of the landraces and composites in farmers conditions. Data treatments followed ANOVA. Farmers and other stakeholders participated in the demonstration field at Macieira da Lixa and indicated some of their preferred germplasm through a survey.

The tested populations didn't show significant phenotypic differences between the environments, although there were significant phenotypic differences among genotypes for Plant Height, Ear placement and Stalk lodging.

The yield ranged from 3635 kg/ha to 10505 kg/ha, with significant higher values in Macieira de Lixa. The germplasm with higher yield were FN- 2014 (10507 kg/ha and 6949 kg/ha) and "VA C0S019 (Regadio Lousada)" (7270 kg/ha and 6247 kg/ha) obtained the higher yield in both environments (Macieira da Lixa and Lousada respectively). Farmers and stakeholders selected in the Macieira da Lixa environment FN-2014 for feed and 'Pg C0S019 (Lousada)' for maize bread purposes, interestingly the higher yield population was not selected "VA C0S019 (Regadio Lousada)". The population with higher stability across environments were the CCP BulkAzores2 that has in their basis 40 populations entries.

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Socio-economic, market and consumer aspects of seed systems

ORGANIC SEEDS AND VARIETIES: CAN THE MARKET DELIVER?

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Keywords: organic seed, markets, consumers, regulation

Seed is an essential input for all food production and vitally important to all of us. In our western society the exchange of seed, like many goods and services, is governed by the rules of the free market.

Economic theory assumes that free markets, where the balance between supply and demand is regulated by price, are the most efficient way to allocate scarce resources. In an ideal market, increases in demand will lead to increases in price and hence more production, resulting in an improved supply. If demand falls, the price will fall, fewer producers will cover their costs and so less will be produced. Bateman (1994) compares Adam Smith's[1] metaphor of the "invisible hand" to a voting system, in which each consumer (or in this case organic farmer or grower) is given the opportunity to express her or his choices and preferences.

The ideal market is assumed to be competitive, i.e., large numbers of buyers and sellers competing freely based on access to perfect information. Many economists and policy makers believe that there should be as little intervention as possible from regulations in any market. This paper will look at the question of whether these assumptions of economic theory apply to the organic seed market, by looking at factors that impact on supply and demand, at regulations and at the availability of information.

The commercial seed market in Europe is an important agricultural input market and large share of supply is concentrated on very few players. The organic seed market is much smaller and difficult to estimate in size. The supply is more diverse, consisting of about 800 larger and smaller seed businesses (breeders and traders) as well as farmers and growers that multiply organic seed crops. There are considerable differences in the level of availability and supply chain organisation between arable, vegetable and forage crops. Supply is concentrated in a few mostly Central European countries, notably France, Germany, Austria, Italy and the Netherlands, with farmers in other countries having to buy imported organic seed. There are also some public breeding and many not-for-profit and community-based initiatives: the so-called informal seed sector. Unsolved technical problems in exist in relation to organic seed multiplication in some sectors (Orsini et al. 2019). At present, revenues from seed sales and royalties account only for a small percentage of return for organic plant breeding (Kotschi and Wirz, 2015).

1 (Smith, 1954 cited after Bateman, 1994)

The demand side is represented by 418,610 organic farmers, of whom some but not all will buy organic seed; those who save their own or exchange seed do not participate in the market. In all three sectors the organic land area increased in the last decade, leading to increased demand for organic seed. The use of untreated conventional seed under derogation is still common for most crops and in all European regions (Willer et al. 2020; Orsini et al. 2019). Using organic seed has cost implications for farmers but this does not appear to be a major barrier for many farmers, indicated by a positive attitude towards organic seed use among surveyed farmers. When asked about what actions would increase the likelihood of organic seed use, producers refer to choice of varieties and more efforts in breeding for organic farming rather than more organic seed multiplication (Orsini et al. 2020). Organic consumers interact only indirectly with the organic seed market through the products they choose. Their attitude to organic seed has not been studied in detail. Based on other research it appears unlikely that many consumers would be willing to pay any additional premium for the use of organically grown seed, with the potential exception of the use of varieties that have better nutritional qualities.

Regarding access to information the organic seed market in Europe has many shortcomings. Variety trials that provide producers with information about the suitability of cultivars only exist in 13 European countries with established markets and mainly for arable crops, in particular wheat species. Organic seed databases provide some information on availability of organic seed, but do not contain data on price and do not operate across the whole of Europe.

The organic seed market is also influenced by two regulations mostly impacting on the demand side: (a) the organic regulation requiring the use of organically multiplied seed (with derogations possible); and (b) the certified seed marketing regime that requires producers to choose registered varieties and certified suppliers for many crops. The aims of the two regulatory systems are not aligned, which is illustrated by the many debates about agrobiodiversity, farmers' rights to seed sovereignty and the privatisation of plant genetic resources (Fehér et al. 2019; Kotschi and Wirz 2015).

Conclusions

- The market for organic seed cannot be categorized as a well-functioning competitive market. The answer to the question of the paper is "no", the market alone cannot deliver organic seed.
- Demand is larger than supply, indicated by the continued use of untreated non-organic seed in Europe. Growth of the organic land area, as foreseen in the European Farm to Fork and Biodiversity strategy, is likely to lead to further substantial increases in demand.
- Organic seed supply for most crops is concentrated in the middle of Europe, in countries with well-developed organic markets. Producers elsewhere have to rely

on imported organic seeds and thus varieties commonly grown in the exporting countries.

- Information is lacking about the performance of varieties under organic conditions, about availability and price and about the area on which untreated non-organic seed is used.

- Given the current poor functioning of the organic seed market as well as technical problems in many sectors, it is unlikely that increase in demand will result in further investment in breeding and increases in organic seed production. This is confirmed by the fact that despite current demand exceeding supply, the organic breeding sector is characterised by a shortage of funds.

- Under such circumstances, tightening of the organic regulation could have many unintended consequences, including a loss of delivery of public goods by organic agriculture, in particular in relation to high agrobiodiversity.

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ASSESSMENT OF POLICIES AIMING AT BOOSTING ORGANIC SEED USE

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Keywords: organic seed, policy, value chain

In the EU, market failure can be observed for organic seed and cultivars, with the seed market being dominated by conventionally bred varieties and conventionally multiplied seed (Döring *et al*., 2012). By 2036, the EU plans to achieve 100% organic seed for the sector (New Organic regulation 848/2018). However, there is not yet a strategy in place on how to secure sufficient organic seed supply. The conflicting interests of different value chain actors and the lack of implementation of the current EU Organic Regulation 834/2007 contribute to the failure of the organic seed market. Thus, we propose an ex-ante value chain assessment approach to evaluate potential strategies to boost the organic seed sector.

To develop a suitable ex ante assessment tool, different existing approaches were evaluated, combined and extended. As actors along the seed value chain and actors at each level of the chain feature heterogeneity, a multi-agent system was considered best suited when modelling the seed value chain. Mathematical programming is used to simulate the decision-making behaviour of the agents. Based on standard microeconomic theory, it allows flexibility for agent behaviour by offering a vast range of decision options (Schreinemachers and Berger, 2006). The proposed model was developed and parameterised for 3 different case studies, i.e. the seed value chain of organic carrot production in Germany, of organic durum wheat production in Italy, and organic perennial ryegrass as permanent pasture in England. The chosen crop-country combinations represent important and at the same time diverse seed value chains.

Preliminary results for the wheat and carrot cases show that a sole phasing out of derogations for the use of conventional seed causes a loss in farm enterprise gross margin. This loss is not as substantial in the case of organic wheat production as in the organic carrot case. However, in both cases it seems to be wise to mitigate by introducing a subsidy at seed price level to smooth transition. Furthermore, a step-wise phasing out of derogations seems advisable, so that organic seed production can be gradually and continually expanded by seed companies. Otherwise, a shortage of seed production side could occur. In the organic wheat case, a stronger focus on farmers' own organic seed multiplication seems be an affordable way forward.

All in all, a combination of command and control measures as well as economic incentives to increase organic seed use and production are promising measures to overcome the organic seed market failure. Some individually adapted country-crop specific interventions may likewise promote success.

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APPRAISAL AND USAGE OF ORGANIC SEED IN EUROPE FROM ORGANIC FARMERS' PERSPECTIVE

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Keywords: Europe, organic farmers, organic regulation, organic seed

The new European Organic Regulation 2018/848 entering into force in 2022 aims to phase out derogations for the use of untreated non-organic seed by 2036. At present, however, the use of organic seed by organic farmers in Europe is low (Döring *et al*., 2012; Solfanelli *et al*., 2019; Orsini *et al*., 2020). We present the results of an online survey on the usage of organic seed with a network sample of 749 organic farmers in Europe, conducted in 2018 and 2019 (Orsini *et al*., 2020).

Our findings reveal significant differences in organic seed use by different crop sectors and groups of farms – including between farms operating in 'alternative' and 'mainstream' food supply chains, between smaller and larger farms, between established and more recently converted organic farms, and finally between farms located in different geographical regions. Farm saved seed plays an important role in the coverage of organic seed demand especially in Eastern and Southern Europe.

From an attitudinal and behavioural perspective, the main critical issue reported by the surveyed farmers is the availability of organic seed for the varieties they need, especially in Southern and Eastern European countries. Farmers' behaviour relating to the use of organic seed is mainly influenced by their perception of societal expectations, particularly from the consumer and the organic certifier.

In conclusion, based on this survey the phasing out of derogation of untreated non-organic seed for organic production across Europe is a great challenge. The local capacities to supply organic seed of a large range of crops species and adapted cultivars should be improved to meet farmers' demand, so that crop and market diversification is not at risk. From the demand side, the communication of societal expectations in the public and political discourse can potentially stimulate the use of organic seed.

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FUNDING ORGANIC PLANT BREEDING AND THE POTENTIAL IMPACT OF OPEN SOURCE SEED SYSTEMS

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Keywords: open source, intellectual property rights, organic breeding

With the extension of organic farming, the need for well adapted cultivars is growing rapidly. The use of organic seed is legally required, organic cultivars are essential to exploit the full potential of organic production and both are increasingly demanded by consumers. But the development of organic plant breeding and seed production has not kept up with the increase of the area under organic cultivation in Europe. Lack of financial resources for organic plant breeding is commonly seen as a main reason. Therefore, new business models were identified and the potential impact of open source seed systems on funding of organic plant breeding was analysed.

In the years 2015 and 2016, Agrecol analysed the status quo of funding and discussed solutions to improve the situation. An international survey and interviews with breeders served to assess sources of funding (Kotschi and Wirz, 2015). Testing a new strategy to protect seeds as commons with an open source licence focused on finding non-proprietory concepts of financing. An interdisciplinary international workshop with breeders, seed producers and commons experts explored alternative financing concepts in the context of seeds as commons (Kotschi and Doobe, 2019). In addition, an open source wheat cultivar was developed and promoted along the value chain. An "open source bread" was used, to analyse the potential, of involving consumers in funding organic breeding.

The survey confirmed the limited funding as a main constraint for the extension of organic plant breeding. Interestingly, the largest share comes from donations, a smaller part from seed sales, whereas royalties from plant variety protection (PVP) - the classical source of funding - contribute little or nothing to finance plant breeding. A survey among cereal breeders revealed that foundations alone contributed 35-81%, whereas royalties from PVP contributed 0-12% to cover the costs for breeding (Kotschi and Wirz). There are various reasons which explain why funding based on intellectual property rights (IPR) had little impact: i) the area under cultivation with organic cultivars is too small to generate sufficient income from royalties, ii) large scale production based on few cultivars contradicts the need for diversity in organic cropping systems and iii) the majority of organic plant breeders consider their cultivars a commons and reject IPR.

In search for alternatives, no general solution was found, but various new business models were identified. The most promising are i) to involve various stakeholders in the value chain, ii) to introduce a label for non-proprietory organic plant breeding and iii) to establish community-based plant breeding.

A combination of approaches could become a powerful alternative strategy to increase the overall budget for organic plant breeding significantly. An approach based entirely on non-proprietory plant breeding and free of IPR is seen as being more promising as a mixture of both. The positive reaction of consumers to the Open Source Seed Licence (Kotschi and Horneburg 2018) on e.g. an "open source bread" at the end of the value chain suggests that applying the open source strategy outweighs the disadvantages of renouncing royalties.

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EUROPEAN ORGANIC CONSUMERS' ATTITUDES AND ACCEPTANCE OF NEW PLANT BREEDING TECHNIQUES FOR CROPS

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In recent years, the development of new plant breeding techniques (NPBT) have gotten the attention of producers, policymakers, researchers and consumers. NPBT are a variety of heterogeneous methods that allow the development of new plant varieties with desired traits, overcoming some of the limitations of conventional breeding techniques (Schaart et al., 2016). However, given that NPBTs are not a uniform group of methods, conflicting views exist over their implementation in the production of organic food, especially regarding genome editing modifications (Zimny et al., 2019).
Although previous studies have focused on several economic, social and environmental advantages of the NPBT (Shao et al., 2018), there are also opposing views that emphasize the potential human health, environmental and technological risks (Qaim, 2020). In fact, the Grand Chamber of the Court of Justice of the European Union (CJEU) ruled in July 2018 that any organism obtained through NPBT that applies mutagenesis will be classified as a genetically modified organism (GMO) (European Parliament and Council of the European Union, 2018; Purnhagen et al., 2018). Political influence and social acceptance can significantly influence consumers attitudes and acceptance of products developed with NPBT (Lassoued et al., 2018).
Moreover, consumers are critical of the use of many new technologies in the food production processes (Lusk et al., 2014). However, only few studies have focused on analysing the consumers attitudes and acceptance of NPBT in food production processes (Tanaka, 2017). Moreover, many consumers are turning to organic foods, as these products are perceived safer, more natural, with higher quality and as an ethical choice (Zander et al., 2015; Zanoli et al., 2013). Nevertheless, no previous work has studied the perception of organic consumers on the implementation of NPBT seeds in organic food.
The aim of these study is to study the European organic consumers attitudes and acceptance of NPBT seeds in organic food production. Data was collected through an international survey and a DCE in eleven countries: Denmark, France, Germany, Hungary, Italy, Latvia, Netherlands, Slovenia, Spain, Switzerland and the United

Kingdom. Using a stratified random sampling approach, 400 responses per country were collected. All respondents were organic consumers and fully or partially responsible for the food shopping in their households.

Results show that organic consumers prefer non-hybrid seeds over hybrid or NPBT seeds. However, some European organic consumers seem more willing to accept NBPT seeds if the product presents additional nutritional benefits. This matches with previous studies (Colson and Rousu, 2013). Moreover, results show heterogenous preferences among consumers. Further research is needed to understand in detail such heterogeneity.

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CONSUMER PERCEPTIONS AND EVALUATION OF THE OPEN SOURCE SEEDS LICENSE

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Keywords: open source, biodiversity, consumer research, seeds, sustainability

Current developments in the global seed industry raise environmental, social, and economic sustainability concerns. This includes the decline of agrobiodiversity, reduced access to plant genetic resources, as well as privatization trends that lead to power imbalances. In this context, open source initiatives emerged worldwide in the breeding and agricultural sector aiming to safeguard agrobiodiversity and counter those trends in the seed industry. Open source initiatives aim to foster seed sovereignty through promoting diverse, locally adapted varieties, especially for organic agriculture, restoring crop seeds as common goods, and combatting market concentration in the seed industry. In Germany, the non-profit association OpenSourceSeeds developed and introduced an Open Source Seeds License (OSSL) that is attached to seed bags. It grants its users the freedom to (i) save or grow seeds for replanting or for any other purpose, (ii) share, trade or sell seeds to others, (iii) trial and study seeds and share or publish information about it, and (iv) select or adopt seeds, make crosses, and breed new lines and varieties (Kotschi and Horneburg, 2018). Any form of privatization is prohibited.

An introduction of an open source seeds label or symbol for food products could potentially raise consumer's awareness on agrobiodiversity and sustainability concerns, leading to demand-driven shifts in seed production. However, so far there has been no empirical research on consumers perceptions and evaluations of open source products in the food and seed sector. Consumer research related to seed production and breeding is so far limited to studies on the perceived risks and benefits of genetic engineering.

The aim of our study is to empirically explore how consumers perceive and evaluate open source food products by the example of the OSSL. We investigate this through a primarily qualitative analysis of 228 thinking aloud protocols, which we collected in an organic and a conventional supermarket in Berlin, Germany, in summer 2018. Thinking aloud protocols are an exploratory method to examine consumer's reactions on a stimulus (Ericsson and Simon, 1993), in this case a flyer on the OSSL. Five flyers served as stimuli and each version used a different rationale for introducing the OSSL. This allowed us to explore which themes resonate most with participants. The rationales were: (1) loss of agrobiodiversity, (2) high levels of market concentration in the global seed sector, (3) privatization of plant genetic resources through intellectual property rights, (4) open source principles as democratic means of production, and (5) the need for cultivars specifically developed for organic agriculture.

With our study, we address two main research gaps, leading to a better understanding of (1) the perceived relationship between open source licenses and sustainability in the seed sector, and (2) the potential of open source seeds licenses to communicate sustainability challenges and generate demand for open source produce among consumers.

Results show that most consumers have a highly positive evaluation of open source produce, regardless of whether they fully understand the concept or not. Overall, we observed that the flyer pointing to the loss of agrobiodiversity and the flyer on privatization and intellectual property rights resonated most with participants. Aspects on agrobiodiversity particularly appealed to participants who had personal gardening experiences as well as to older participants that remembered varieties that are no longer commonly available. The flyer on privatization and intellectual property rights primarily engaged participants that were concerned about the influence of large-scale agribusiness on food production. General open source principles as argumentative entry points were often considered to be too abstract.

Communicating the added value of OSSL products would require target-group specific explanations, which are easy to understand and highlight the immediate benefits and relevance for consumers. Since the term open source 'license' was counterintuitive for many participants, consumer communication should refer to open source seeds/ tomatoes/produce etc., to avoid confusion. As communicative tool, open source may primarily appeal to younger and middle-aged, well-educated consumers that are either tech-savvy or familiar with open source as concept, or have a heightened awareness for sustainability concerns. Especially organically-minded consumers may be a key target group for open source produce as they usually have a higher willingness to engage with the circumstances of food production.

Our results confirm the notion that there is a general societal consensus on the importance of preserving and enhancing biodiversity and supporting small-scale farmers. To what extend the observed positive associations with the OSSL would translate into consumer demand for open source produce requires further exploration.

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CONSUMER PREFERENCES FOR HEALTHY MINOR CEREALS

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Keywords: consumer preferences, minor cereals, bread

This study was conducted in the frame of the FP7 project HealthyMinorCereals which aimed at the diversification of cereal production in Europe through breeding programs for rye, oats, spelt, emmer, and einkorn. The objective of this study was to investigate the role minor cereals play in people's food consumption in Europe. Specifically, we aimed to examine (1) if consumers know minor cereals (knowledge), (2) how consumers perceive minor cereals (perceptions), (3) if consumers are willing to pay more for foods made from minor cereals (preferences), (4) and how consumer knowledge, preferences, and perceptions differ between different European countries.

For this purpose we conducted a standardized online survey in five European countries, including Germany, Czech Republic, Estonia, Hungary, and the UK. For sampling and data collection the market research firm Bilendi was contracted. The survey took place in June 2018 and lasted 20 minutes. It was divided into five sections: introduction and screening, knowledge and consumption frequency of foods made from minor cereals, preferences for bread made from minor cereals, perceptions of foods made from minor cereals, sociodemographics and ending. In each country a representative sample of at least 600 consumers was reached.

The majority of consumers of all five countries knew the minor cereals rye (83% to 97%) and oats (92% to 98%). With respect to spelt, einkorn, and emmer there were significant differences in knowledge between the five countries. Spelt was best known in Germany (94%), followed by Hungary (81%), and Czech Republic (77%). In Estonia and the UK, spelt was known only by about half of the participants. For einkorn and emmer people's knowledge was significantly lower. Einkorn was best known in Czech Republic (40%), followed by Germany (28%), and Estonia (15%). In Hungary and the UK only 7% and 4%, respectively, had heard about einkorn. Emmer was best known in Czech Republic (33%) and Germany (19%) and significantly less in Estonia (4%), Hungary (7%) and the UK (4%).

From a total of seven bread types, respondents indicated to consume most often pure wheat bread, multigrain, or rye bread. Rye bread was most popular in Estonia, with 77% consuming rye bread at least once a week, and 36% consuming it on a daily basis. In the UK, rye bread was least popular, with only 7% consuming rye bread at least once a week. The consumption frequency of oat, spelt, and particularly einkorn and emmer bread was generally very low. Spelt bread was most popular in Germany, with 24% consuming spelt bread at least once a week. Oat bread was most popular in Estonia, with 14% consuming oat bread at least once a week.

For respondents from Czech Republic, Germany, and Hungary the discounter, supermarket, and bakery, are the most important purchase channels for bread. In the case of respondents from Estonia and the UK it is the supermarket.

From a total of 16 purchasing criteria for bread, ‘good taste’ and ‘fresh’ were clearly the most important criteria in the Czech Republic, Germany, Hungary and the UK. In Estonia, it was these two plus ‘wholemeal’, which had the same importance as fresh. The criterion ‘seldom used grain’ had a very low importance in all five countries.

In Czech Republic, Germany and Hungary more than half of the respondents (55%/ 59%/ 51%) were willing to pay more for grain products made from minor cereals than for comparable grain products made from major cereals. In Estonia and the UK this share was significantly lower (42%/34%). In all five countries, most of the respondents who were willing to pay more, were willing to pay a premium of about 10 to 25%.

The most important reason why respondents were willing to pay more for grain products made from minor cereals was that they perceived them to be ‘healthier’. But also ‘higher in fibres’, ‘more tasty’, ‘food diversity’ and ‘fewer synthetic additives’ were frequently mentioned. One driver that was only important in the Czech Republic and Hungary was ‘easier to digest’. Another one that was only important in Germany, Estonia and the UK was ‘support of smallholder farmers’. Another two that were only important in Germany were ‘handmade’ and ‘biodiversity’.

The overall aim of the project HealthyMinorCereals was to impact cereal diversity in Europe. The consumer study revealed, that wheat is the most known and consumed cereal in the countries investigated. The example of Germany, Czech Republic, and Hungary shows that an increase in cereal diversity could be achieved if consumers are more aware about this diversity and are more interested in it and, as a consequence, valorise it more. Wending et al. (2020) described a growing interest in traditional cereals. In our case, consumers are more interested in health and taste of cereals. Different from other studies (Wending et al. 2020), the interest and awareness of consumers about minor cereals is very heterogeneous. We assume that the local biophysical conditions and connected traditions had an influence on the knowledge of consumers e.g. spelt for Germany or rye for Estonia.

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ANALYSIS OF VEGETABLES SEED SYSTEMS IN GHANA

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Keywords: seed system, quality seed, seed availability, agro-dealers

Seeds are important inputs for agricultural productivity. They are vehicle for dissemination of knowledge and technologies in the agricultural sector. Ensuring food and nutritional security depends on access to good quality seeds of improved varieties. Understanding seed systems farmers use for various crop production is crucial to design tailored interventions to improve their access to good quality seeds. This current study was set out to map the seed systems of three major vegetables, onion, tomato and pepper in Ghana. We used multi-stage sampling to identify the survey locations (major vegetable growing regions, districts and communities) based on expert recommendations and production statistics, and a random walk to identify the respondents' households. In all, 460 households were surveyed of which 180 were for tomato, 150 were for onion and 130 were for pepper across eight administrative regions in the country. Additional information on seed system regulatory framework was collected through Key Informant Interview with seed regulatory officers. The data were analyzed using descriptive statistics, graphs for mapping the stakeholders involved in the seed sector and significant differences test. The results showed that there is legal and institutional regulatory framework for seed sector in Ghana. Seed sources were crop-dependent. Onion (77%) and tomato (65%) growers primarily bought seed for planting while 54% of pepper farmers used saved-seeds from previous harvest. Regardless of the crop, farmers who purchased seeds primarily sourced them from local shops/agro-dealers and other farmers. Seed sourcing from fellow farmers is still an important channel to get seeds, which exemplifies the importance of the informal seed system in ensuring vegetable seeds availability and access. Major reasons that drove seeds purchase from stated suppliers included (i) assured seed quality, (ii) proximity with the seed supplier, (ii) cheaper seed cost and (iii) availability of market preferred varieties. Seed access was region-dependent for the three crops. There was a high variation in the distance farmers travelled to have access to seeds. This distance varied from 0 to 600 km for tomato, 0 to 590 km for onion, and 0 to 216 km for pepper. Overall, vegetable growers are still constrained by seed availability, affordability and access. However, there are opportunities and strengths to tap into to improve the

system. The relatively high seed purchasing behaviour of vegetable growers is very encouraging for seed distributors. Besides, there is a potential business opportunity for seed distributors to improve their proximity with seed users. In the formal seed system, there was no ongoing vegetable seed production within the country. The improved vegetable varieties marketed in the country were imported and almost none of them was registered neither in the national nor in the regional variety catalogue, which is a requirement for commercializing seed in the country. The analysis of the vegetable seed system provides critical information to decision-makers and the seed system actors to improve farmers' access to good quality seeds at affordable cost.

Regulatory & policy opportunities

NEW RULES ON SEEDS IN THE NEW EU ORGANIC REGULATION

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Keywords: organic regulation, seeds, PRM

After a postponement for one year due to the challenging circumstances, especially for the certifiers, the New Organic Regulation (2018/848) will enter into force on 1. January 2022. This new regulation will bring about substantial changes and new opportunities for organic production with the regard to plant reproductive material (PRM). These new rules define the corridor alongside which the market for organic PRM will develop in the next years and its impact must therefore not be underestimated.

The analysis of the upcoming regulatory framework is based on the basic text of Regulation (EU) 2018/848, as published in the Official Journal of the European Union. Regulation 2018/848 is specified by a number of Delegated Acts and Implementing Acts as well as its respective annexes. The material has been analyzed in a qualitative content analysis to identify the intentions of the legislator and analyze the implications of the Regulation for the (organic) stakeholders.

The New Organic Regulation specifies the different types of PRM available for organic producers, including organic PRM (organic seeds, organic varieties suitable for organic production, organic heterogenous material, farm-saved seed), in-conversion PRM and untreated non-organic PRM. The text defines the rules under which in-conversion and non-organic material can be used and specifies in Article 53 an end for derogations (to use non-organic seed) by 2036, thereby marking the date by which 100% organic seed shall be achieved. With organic heterogenous material (OHM), the regulation introduces and specifies a novel type of PRM that is exclusive to organic farming at the moment. Next to that, the Regulation sets the framework for a 'database 2.0' for organic PRM and lists the functionalities that the national databases shall offer. Another substantial change is the introduction of a list of species and varieties for which suitable organic or in-conversion PRM is available in sufficient quality, which simplifies the process of variety choice for producers.

The New Organic Regulation is a major step ahead, compared to the previous Organic Regulation. With the introduction and definition of *organic varieties suitable for organic production* and *OHM*, for example, the choice of organic PRM for organic producers has become more diverse. Furthermore, the definitions provide a guiding framework for 'breeding for organic' and specify the timeframe by which derogations are to be phased out. However, there also remains some unclarity about how *OHM*, as defined in the regulation, will be picked up and accepted by breeders, organic producers as well as consumers. Nevertheless, the 1st of January 2022 will mark an important milestone in the quest towards 100% organic seed.

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COLLECTING COMMITMENT IN 10 EU MEMBER STATES – THE ORGANIC SEED DECLARATION

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Keywords: stakeholder involvement, participation, organic seed

The paper presents a conceptual framework to gain stakeholder involvement and active participation to jointly foster the development of the organic seed sector. The organic seed declaration is a voluntary agreement that is signed by all participants after a workshop. It contains concrete action points that the workshop participants are planning to take in the coming year. The aim of this declaration is to increase commitment from and cooperation between stakeholders. Furthermore, it helps to monitor progress. The organic seed declaration has been tested and implemented in 10 EU Member States and has shown to reach high acceptance by the participants resulting in a high number and diverse range of concrete action points.

According to the current EU organic regulation (EC No 889/2008), the use of organic seed is mandatory for all organic farmers whenever available. Shortages in the availability of organic seed led to a high number of derogations for the use of non-organic seed in several EU Member States (Döring et al., 2012). To reduce the extensive number of derogations, the production and use of organic seed must be stimulated. Organic farmers need a broad range of varieties suitable for their growing conditions and market demands. Due to lack of availability of organic seed from suitable varieties and the higher price of organic seed, they continue to use conventional seed (Orsini et al., 2019). Besides organic farmers and seed producers, there are many other stakeholders involved, who can directly or indirectly impact the production and use or organic seed. For instance, control bodies, competent national authorities and researchers. Based on the given preconditions, there is a need to develop a concept that creates commitments from all actors to promote the production and use of organic seed across Europe.

The organic seed declaration as stakeholder commitment concept was developed in five phases: Firstly, status quo analysis of all 28 EU countries through desk research. Secondly, selection of suitable case countries. The evaluation scale was based on the following (i) high number of yearly reported derogations, (ii) limited national availability of organic seed, and (iii) limited data available on the national organic seed market and actors. Thirdly, one-on-one interviews with all relevant stakeholder groups in the selected countries, identifying their attitudes towards organic seed and how production and use of organic seed could be stimulated. Fourth, literature review on how to gain consent and commitment among stakeholders from different disciplines.

Lastly, the implementation of the commitment concept during a national workshop in the selected countries.
Bulgaria, Estonia, Greece, Hungary, Italy, Lithuania, Latvia, Poland, Romania and Spain have been selected as the 10 case countries. A national workshop has been set up for each country to implement the organic seed declaration as concept of commitment. The number of participants per national workshop varied per country between 35 and 80 people. In all except one country (Italy), the workshop resulted in an organic seed declaration signed by all or at least most of the participants. Due to time limitations and the workshop set up, the participants of the Italian workshop did not sign their organic seed declaration. Nevertheless, the group discussion revealed several potential action points and commitments. The commitments of the other nine case countries can be assigned into one of the following four categories (i) improvements of national seed databases, (ii) implementation of incentives to increase production and use of organic seed, (iii) increase information on varieties suitable for organic production, and (iv) increase cooperation among the stakeholders.
The preliminary results reveal that participants show a high motivation to commit to concrete action points in order to move forward. Based on the participants' feedback, there have only been a few to none of such national workshops bringing together actors from all stakeholder groups to jointly discuss a subject related to organic farming. From 2003-2013 the European Consortium of Organic Plant breeding (ECO-PB, 2013) has conducted several stakeholder workshops to foster the development of the organic seed sector. However, often only central European Member States have participated in theses workshops. Further workshops promoting the national and transnational exchange of information are needed to harmonise the implementation of the rules for organic seed in the organic Regulation.

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THE NEED FOR NATIONAL ROADMAPS TO COME TO 100% ORGANIC SEED

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Keywords: regulation, policy, organic seed, stakeholders, roadmap

Since almost 30 years the use of organic seed is obligatory in European organic farming, whenever available. In case of insufficient availability, farmers can ask for an authorization from the competent authority to use non-organic seed. In the new organic regulation EC 848/2018 it is defined that derogations should be phased out by the end of 2035 for all plant reproductive material. In practice however, anno 2021, non-organic seed is still widely used in organic farming and in several EU member states there is hardly any certified organic seed on the market. This raises the question what is lacking in the current regulation and policies for organic seed.

Within the LIVESEED project the national implementation of the European rules for the use of organic seed has been studied in detail. For this 10 countries were visited (Raaijmakers et al., 2019). and a status quo analysis was conducted for in total 21 EU countries. In addition all 28 EU national seed databases were analyzed. To find out what is needed to increase the production and use of organic seed, 7 national, one regional and 3 international workshops were organized involving all relevant stakeholders.

It was found that although the basic legal requirements, of having an organic seed database and applying rules for derogations, are met in most EU countries, this is not sufficient to encourage the production and use of organic seed (Raaijmakers et al., 2019).

Seven, mainly Central European countries, have implemented additional policy measures in the form of a national non-derogation list. Clear criteria are used to define when crops or sub-crops can be moved to this list and expert groups are established to involve stakeholders. For several crops the non-derogation list has proven to be an effective tool to reach 100% organic seed use on a national level and having such a list will be obligatory in the new organic regulation.

But also the non-derogation list has its limits. For instance in cases where the main varieties organic farmers use come from seed companies that do not invest in organic seed yet.

During the international workshop in June 2020 it was concluded that, in order to reach 100% organic seed by the end of 2035 a stepwise, proactive and comprehensive approach is needed. A policy in which all relevant stakeholders are involved and commit themselves to making progress. A roadmap to 100% organic seed with intermediate objectives and a description of the actions required to achieve this ultimate goal (Raaijmakers et al., 2020).

Smart practices presented during the international workshop show how this can work in practice. In France, for instance, the government has developed a binding and progressive timetable for carrot seed. This means the percentage of organic carrot seed that the French farmers must use is increasing yearly. By announcing in time when the goal of 100% organic seed must be achieved, both growers and seed producers can prepare for this. On the one hand it gives the farmers the time to try our new carrot varieties, for which organic seed is already available. At the same time seed companies are stimulated to enter the organic market if they want to maintain their organic market share.

More work is needs to be done to develop a clear format for the design and implementation of roadmaps to 100% organic seed. Since the starting situation differs greatly from country to country, a country-specific approach seems necessary. The obstacles that need to be solved and the steps that need to be taken to reach 100% organic seed may also differ per crop. Therefor also crop-oriented solutions need to be developed. Preferably the roadmaps are implemented in the national organic action plans.

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ASSESSING VARIETIES FOR ORGANIC FARMING: WHAT CONTRIBUTION FROM EVALUATION IN CONVENTIONAL FARMING?

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Keywords: varietal assessment, registration, organic farming

Is it necessary to experiment varieties specifically in organic farming (OF) to assess their adaptation to OF, especially for national listing? The question is divisive, studies providing evidence that assessment in OF is necessary or, conversely, is not. Based on the results of a recent research project (ECoVAB) and other studies, we evaluated the possibility of using results from conventional farming (CF) trials to predict the behaviour of varieties in OF. On this basis, we formulate proposals for evaluation schemes in order to register varieties that are adapted to OF.

The possibility of using references from CF to predict the behaviour of a variety in OF depends on:

- the gap between OF and CF management according to the species. For example, the variety x crop management interaction on yield is greater in wheat than in soybean, for which in CF there is no nitrogen input and very few phytosanitary treatments.
- the level of intensification in trials (amount of input including irrigation), which influences the amplitude of the gap between CF and OF. For example, in Switzerland, "CF" variety trials are conducted in "extenso" (without fungicide, little nitrogen), so their results can be considered as predictive of varietal performance in OF (Schwärel *et al*., 2006).
- the pedoclimatic situations which impact both yield potential and pest pressure.
- the range of genotypes under study.
- the observed traits: by definition, the highly heritable traits (e.g. in wheat: earliness of heading, specific weight) are identical whatever the cropping systems whereas others traits (e.g. yield) are closely in interaction with the environments and cropping systems. The traits showing the highest variety x crop management interactions are mainly related to crop quality: for instance, this is the case for the technological value of wheat, which depends on protein content and protein quality (Le Campion *et al*, 2013).

In addition, trials that compare the behaviour of varieties in OF and CF have certain limitations. Varieties are generally tested on two different plots (one in OF and the other one in CF), which are more or less similar in terms of soils and micro-climates. Crop management (OF/CF) is not the only difference. As for studies based on historical data sets (Fontaine *and al*., in press), they also contain many sources of confusion: trials carried out in different years and geographical areas, few varieties common to the 2 networks. These comparisons are, in a way, useless and endless.

These variable results in terms of predictability (Gutzen, 2019) nevertheless may suggest that it is possible to construct a continuum of varietal assessment between OF and CF, provided that it is designed according to the species, the traits considered, the genotypes tested and the test conditions (level of input use, pedoclimate). Consequently, it is not necessary to systematically duplicate the evaluation networks in OF and CF, but it is a matter of making them work together, each one being able to mobilise results from the other.

To meet the expectations of the OF sectors in terms of varieties, it is necessary to start from the needs of OF -which are plural-, to integrate the additional characteristics required by OF (competitive capacity, initial vigour, ability to grow in mixtures and associations, efficiency for nutrient up-taking, quality for local outlets...), then to determine the data to be acquired in OF in addition to the data from the CF relevant to OF. The final step is to base the registration decision on the traits of interest for OF.

Varietal evaluation systems, and in particular the part of the experiment conducted in OF, would be different depending on the species. For common wheat, yield and quality evaluation should be conducted in OF conditions in a specific network, while disease and lodging resistance can be assessed in CF (this system exists in France and other country). Whereas for a crop such as soybean it is possible to build a single network including sites in CF and OF this system exists in Austria and is under study in France, with the additional description of the covering ability). In order to adapt the VCU regulation process to OF for a large diversity of species, it appears necessary to use both this potential varietal continuum between OF and CF, and the consideration of characteristics of significant interest for OF (currently not or barely evaluated). In addition, a reinforced presence of OF in post-registration networks is expected, to explore a wider range of production conditions. Besides, in order to help users to appropriate references, variety platforms in OF are essential, as they are privileged places for discussion, where everyone can visually appreciate the varieties and share experience.

This VCU approach, built to meet the needs of organic farming, will allow the registration of varieties adapted to organic farming. It can also be used for temporary testing of organic varieties suitable for organic production (regulation EU 2018/848).

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Sustainability

PARTICIPATORY ORGANIC COTTON BREEDING APPROACH TO ACHIEVE SUSTAINABLE DEVELOPMENT GOALS

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Keywords: organic, cotton, seed, SDGs, PPB

At present, about 33 million ha of cotton are grown worldwide, which gives about 82 million tons of seed cotton (FAO 2021) only 0.5% is the share of organic cotton. Organic cotton cultivation on 418'935 ha in 19 countries grown by 222,134 farmers and results in 239,787 tons of organic lint (Textile Exchange 2020). Importance of cotton for rural farmers' livelihood is evident from the number of smallholder farmers involved in cotton production e.g. 51% of the global organic cotton is produced in India by 166,767 families (Textile Exchange 2020) with an average of 2 ha only (Riar et al., 2017). Challenges for organic cotton are more pronounced than ever. The introduction of GM cotton in 2002 has radically changed the cotton species grown in India, affecting the organic (non-GM) seed market, which led to depleted supply and poor quality of available non-GM seed. Also, Bt-cultivation (Genetically modified; GM) has also shifted the natural balance of pest by worsening non-Lepidopteran pests' predation due to increased fertilizer use coupled with pink bollworm Bt resistance has a spilled-over effect on organic cotton cultivation. To tackle these challenges, the organic cotton sector is in the dire need of non-GM seed with improved agronomic performance, high fiber quality, adapted to the various local organic growing conditions, and high resilience towards climate change. To achieve this Participatory Organic Cotton Breeding approach was introduced to organic cotton growers in India in 2011, to improve the availability of non-GM cotton seeds of improved cotton cultivars suited explicitly for organic farming systems. This is fundamental to guarantee the integrity and credibility of the organic value chain. Moreover, this will enhance the competitiveness of organic cotton and the income security and autonomy of smallholder cotton farmers. In this paper, we briefly evaluate the role of Participatory organic cotton breeding (POCB) to achieve the U.N. Sustainable Development Goals — also known as Global Goals or the SDGs. POCB can contribute to all 17 SDGs due to their interlinkages; however, a thorough evaluation of methodology indicates the POCB directly contributes to 6 SDGs, and six more SDGs can be contributed indirectly. POCB potential and approach toward resilience will improve choice and access to adapted seed, fast adoption of new cultivars, create more income in rural areas, and empower farmers (SDG 1). POCB will support the transition to more sustainable textile production by reducing the application of toxic pesticides. This is of significant importance as cotton still demands lots of labour in the field for spraying and picking mainly done by female farmers. Risk of pesticide residues will be reduced on neighboring food crops. Furthermore, POCB will promote organic cotton textile growth with much stricter rules on chemicals allowed for textile dyeing and finishing. It will ensure healthy lives and promote the well-being of farmer families and textile workers (SDG 3).POCB is a knowledge-intensive process involving many stakeholders like farmers, extensionist, breeders, seed companies, ginners, spinners and textile trade, as well as socio-economists. After a trust-building process, POCB fosters mutual learning among the partners and contributes to capacity building in rural areas (SGD 4). Active involvement of female farmers in POCB and seed saving has proven to be especially rewarding, as they show a different perception of breeding goals and greater endurance. Their active engagement improves their social status and at the same time, improve the breeding process (selection for easy picking traits) and seed security (SDG 5). Decentralized POCB for high resilience and robust cultivars and breeding for locally adapted more diverse farming systems and different agroecological zones will reduce the risk of crop losses due to climate change. The large number of on-farm trials in the scope of POCB allows identifying new challenges (like emerging pests and diseases) as well as selection for extreme weather conditions (e.g., delayed or interrupted monsoon rains, flooding, cool temperature). Reduced fertilizer input will also mitigate greenhouse gas emissions (SDG13). Participatory Organic Cotton Breeding can become a model for the closer collaboration of government, private sector and civil society. Defining breeding as a societal challenge will shift relations between the different actors of society. In order to allow biodiversity to enter the market, political and legal changes are required (SDG 17).

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IMPLEMENTING THE SYSTEMS-BASED BREEDING CONCEPT

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Keywords: ecological and societal resilience, breeding strategies, systems-based breeding, implementation

Society is becoming more and more critical on variety development strategies, not only at the technical level, but also at the level of cultural and ethical aspects of breeding. Lammerts van Bueren et al. (2018) analysed several challenges towards ecological and societal resilience and six sustainability goals have been defined: 1) food security and safety, 2) food and seed sovereignty, 3) social justice, 4) agro-biodiversity, 5) ecosystem services, and 6) climate robustness. These can only be properly addressed by concerted action. Therefore, the concept of systems-based breeding aims to integrate the strengths of different breeding orientations and provides a perspective where breeders can be initiators of developments towards an ecologically and societally resilient crop production. This paper presents the first steps for operationalising this concept.

To find ways to implement the concept of the systems-based breeding, this approach has been discussed with organic breeding practitioners and with actors of the value chain in five workshops in 2018 and 2019 in the frame of EU-Horizon 2020 project LIVESEED and beyond. To be able to operationalise this methodological orientation and internalise this concept in the daily practices of plant breeding, practitioners will need to reflect on how they are currently managing their breeding, and how they can adjust their breeding practices in the future, including the socio-cultural and ethical aspects. Collaboration and value chain partnerships seem to be key elements for change towards both ecologically and socially resilient food systems.

In order to achieve resilient food systems, it should not only be a government or a strong civil society pushing for a diversity of approaches, but gradual change should also come from within the breeding sector. In one of the workshops two different organic breeding companies each assessed their present status in respect of 12 key elements and defined their own future targets for improvements in 5 and 10 years' time. As a way to inspire each other they then presented and jointly discussed the formulated targets and critically questioned each other on the motives and feasibility. Research on multi-actor approaches showed that a continuous critical evaluation through reflection of the whole process is needed in order to develop and play a transformative role (Rossi et al. 2019). This helps to manage the process fruitfully and coherently in relation to the commitment to contribute to generate change towards resilient food systems.

The higher the diversity in breeding approaches and the more initiatives, the more agrobiodiversity can be maintained and bred for, which is also important to make agriculture more climate robust. In addition, diversity in breeding approaches and initiatives will foster the development and maintenance of knowledge, and it will help keep an open mind on what seeds are: they are not only commodities, but that they are also culture and part of our common heritage.

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SUSTAINABILITY ASSESSMENT OF BROCCOLI *(Brassica oleracea* var. *italica)* PRODUCTION WITH DEFICIT IRRIGATION SYSTEM IN SICILY

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Keywords: *Brassica oleracea* spp, sustainability assessment, LCA, water stress

Climate change, global population increase and economic growth have led to numerous changes in water consumption patterns, in addition to a profound change in the availability of this resource. In the last decades there has been a different seasonal availability of water, variability of the river basin flow rate and the increased phenomenon of ground water sedimentation. The agricultural sector is the main responsible for the water consumption, which is often excessive compared to the real needs of crops because it is operated through a bad management of this resource. In general, the crop's need does not correspond to the amount of water drawn that often exceeds the real requirement, and this leads not only to an inadequate use of water resources but also the lack of availability for the population and other activities reducing its value.

The BRESOV H2020 European project “Breeding for Resilient, Efficient and Sustainable Organic Vegetable Production”, deals with the importance of water consumption in order to rationalize the use of water resources through the identification of a hybrid genotype F1 (Marathon) resistant to water stress.

The Mediterranean vegetable heritage lends itself to the evaluation of deficit irrigation systems with the aim of demonstrating the possibility to obtain excellent productive results even with a lower contribution to the real needs of the crop. The analysis was performed on the species Broccoli landraces. The trial was conducted by dividing the field into three plots, each with a different dose of irrigation: the first one was characterised by a standard irrigation regime, reintegrating 100% of ETP (Evapotranspiration), in comparison to water deficit regimes reduced by 55% and 35% of recorded ETP. The three plots have been treated in accordance with the principle of equal conditions except for the distribution of water by drip system. The data related to the experimental results have been analysed both in terms of product obtained by evaluating the qualitative and quantitative traits and in environmental terms through the Life Cycle Assessment (LCA) methodology, in order to highlight the advantages of using a deficit irrigation system to combat climate change and reduce environmental impact. LCA takes into account all inputs used in a production process and provides specific answers in terms of emissions. It allows to quantify the burden on the environment and to identify the most impacting steps in process in order to define the improvement practices needed. The experimental trial, conducted in Sicily (southern Italy), highlighted the advantages of applying the deficit regime, with a 45% and 65% reduction in the water used. Next to a good production, reduction in the environmental impact of the growing process have been recorded both in the 55% and 35% regime. The optimal solution to pursue the objective of environmental sustainability and a satisfactory yield is the application of the 55% dose of the real water requirement. Therefore, it is possible to state that the Broccoli crop in the reference area is easily adaptable to deficit irrigation regimes. This study represents an interesting opportunity for continuing the evaluation of the behaviour of other species belonging to the Mediterranean vegetable heritage in order to favour the transition of the environmentally friendly cultivation systems and to improve the use of exhaustible resources.

SUCCESSIONAL AGROFORESTRY SYSTEMS FOR EUROPE: THE PORTUGUESE EXAMPLE

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Agroforestry is an agroecological practice with a long tradition in European Mediterranean countries and is recently getting more attention from political and scientific communities (Mosquera-Losada *et al*. 2018). The recognition of Agroforestry importance can be found in the CAP post 2020 draft Strategic Plan Regulation, and in the Farm to Fork Strategy and Biodiversity Strategies, which are all part of the European Green deal. Compelled by climatic changes, the search for innovations in agroecological practices is seen as a part of the solution to mitigate Agriculture's impact. The concept of successional agroforestry systems (SAFs) has been developed and tested by Ernst Götsch since 1982 in the state of Bahia in Brazil. These systems are managed to accelerate the succession processes in order to create an agro-ecosystem with structure, function and dynamics similar to the local natural ecosystem. This agroforestry practice has in the last few years evolved to a design inspired in alley cropping systems and named Syntropic Agriculture. It relies on ecological succession and stratification as a replacement for fertilizers and pesticides and pretends to be process-based, as opposed to many conventional or organic practices that are input-based (Andrade *et al*. 2020).

The aims of our work intend to identify and describe the SAFs initiatives in Portugal mainland with the main purpose of understanding how these systems are being implemented in a Mediterranean climate, what similarities they share with the designs from tropical contexts and what solutions are being develop by farmers to adapt to local conditions.

From September to December of 2020, an update inventory of SAFs farms in Portuguese mainland, maintained according to the main principles of Syntropic Agriculture, was done. After identification and a previous contact, the selection of the locations to visit, were defined. From the visited locations the information was collected using a questionnaire applied to the person responsible for the SAFs.

A complete list of species planted during the current year were registered, namely trees, shrubs and herbaceous plants. Focus on commercial purpose was favored for SAFs farms selection and an effort to cover most of the territory was made.

So far eight farms were included in the project. All have a direct or indirect connection with Ernst Götsh. The oldest system was implemented three years ago with the system's areas ranging from 500m2 to 2ha but with a predominance of small-scale fields. Indeed scalability has already been identified as a major limitation of this practice (Andrade et al. 2020) and labor costs and lack of specialized machinery was also pointed out by farmers as major difficulties. Apart from highly skilled pruning required and demanding decisions about the complex consortia composition, other difficulty observed was the unavailability to meet the amount of plant material required to implement the system. Fertilization is still applied in all fields and almost all systems used irrigation. Plant pests and diseases were reported as minimal which could be the result of the multicity of ecosystem services provided by the great plant biodiversity planted. All farms adopted organic farming practices with a few having organic agriculture certification.

With no exception, large numbers of trees, shrubs and herbaceous plants are planted in small areas, with perennials' layout lined up 3 or 4 m apart usually with heavy annual production between lines. In general financial results are still far from desired, with some farms getting income from direct sell of grocery boxes and others more fruit oriented. Interestingly all involved expect financial return in the short or medium term. There are resemblances between the plant species presented in the farms included in the project although a great influence from tropical designs is observed. Some native species, mainly trees and shrubs, were intentionally planted and managed with clear benefits reported. There is a general will to increase the number and variety of tree species in what should be seen as a major opportunity to increase the carbon sequestration potential and also the ecologically intensity of these systems.

Considering the expansion of SAFs throughout the world, Europe included, there is an opportunity to study and better understand these systems in order to optimize them to different climates and soil conditions and improve either the similarity with native forests, in complexity and function, as well as the productivity and financial return.

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ASSESSMENT OF BROCCOLI *(Brassica oleracea* var. *italica)* SEED PRODUCTION FOR THE ACHIEVEMENT OF SUSTAINABLE DEVELOPMENT

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The global scenario in which farmers are operating is characterized by increasing population, environmental degradation and climate change which affect crop production. The European Commission through the Green Deal has established practices to preserve biodiversity, ensure resource use for future generations and reduce dependence on pesticides and fertilizers, with the dual aim of achieving more sustainable production and providing consumers with sufficient food and high nutrient content. The above points are part of the "Farm to Fork" strategy whose aim is to accelerate the transition to a sustainable food system where the product has a reduced environmental impact, mitigates climate change and at the same time contributes to increasing food security. In this way the opportunities for operators in the food value chain are increased and at the same time a role is also attributed to the consumer, who assumes the function of guarantor of product quality.

The Mediterranean vegetable heritage with its wide biodiversity offers the best possible conditions for pursuing these objectives. The *Brassica oleracea* crops thanks to the high number of landraces and wild species has allowed, within the BRESOV H2020 European project "Breeding for Resilient, Efficient and Sustainable Organic Vegetable Production", to set the optimal growing conditions and the agronomic parameters necessary for pursuing good yield and an high quality organic seed by the use of microorganisms under conditions of low inputs.

Three cultivars belonging to *Brassica oleracea* crops, an expression of Sicilian biodiversity often unfortunately undervalued, have been used to carry out the work. These have been placed in the field following an experimental split plot scheme characterized by three replications with seven plants. Each plot was treated by the different doses of nutrients such as amino acids and microorganisms, according to the Itaka srl protocols (IP0, IP1 and IP2). The first was characterized by a dose of nutrition able to meet the real needs of the crop, the second replication provided for a half dosage while the third was not fertilized, with the aim of studying the response and the growth rate of the different cultivars. After 158 days from transplanting, morphobiometric tests were carried out on the plants to evaluate the quality aspects and growth response, allowing the collection of important data such as: plant height, weight, stem basal steam diameters, fresh weight and finally the dry matter produced by each plant. The results obtained show that the future of agricultural production is moving towards an increasingly rational use of materials to reduce pollutants, climate change and negative impacts on human health. There is a strong need to affirm the concept of "minimum dose" in order to obtain a satisfactory result in terms of production and quality. Regarding the Green Deal of the Farm to Fork strategy, the aim of the work is to make farmers aware of the implementation of more sustainable practices, in fact it wants to show that even through a reduced use of inputs in terms of fertilizers it is possible to obtain economically sustainable yields, making the production process environmentally friendly.

The study highlights the limited availability of high quality organic seeds in Europe. It also involves a qualitative-quantitative assessment of the perception that local farmers, potentially interested in Brassicaceae, have of opportunities in the EU "Farm to Fork" strategy.

CONFERENCE TOUR TO ORGANIC FARMS IN LATVIA

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Keywords: organic farming, seed production, honey, rye bread, sheep flocks

Virtual tour to organic farms in Latvia was developed with aim to show diversity of organic farming. Small family farms and large organic companies with more than 25 years of experience, it is clear that organic farming has a promising future.

Conference tour started with small organic farm **“Indrāni”** run by family for three generations. From the beginning organic farm was engaged in livestock and crop production, but now they are recognizable as syrup and jellies producers from 15 unusual plants, for instance dandelion, red clover and spruce needle. Farmers strongly believe that working organically and taking care for their home and land is their duty. Hosts can’t imagine living in other way. Situation in previous year encouraged them to set up their own online store where they can sell goods all produced by themselves. In internet store the offer of farm products is diverse containing around 200 commodities. Now farm is not only home for family and place for production but also a wonderful leisure place for visitors. This farm offers great place for fishing, or just relaxing in sauna. Hosts also invite people feeling sceptical about organic farming offering them to stay for a couple of weeks and to get to know how organic farm works.

Next place for visit was organic farm with 25 years of experience **“Kalna Smīdes”**. The farm is known as the organic honey producer from wild plants as well as from locally grown special nectar plants. The hosts have about 300 bee swarms and believe in an important role of bee not only for agriculture but also for whole humanity. Although, the impact of conventional farming is so high causing failures for organic beekeeping, the farmer feels optimistic and is able to provide different types of honey and other bee products for customers. The company has developed various honey blends, for example, honey with cinnamon, nuts, chocolate, cranberries and plant pollen.

Additionally, the farm has been certified as organic seed producer for five years. The company is main organic seed producer for Latvian winter rye variety ‘Kaupo’. The company obtains high generation seed material from the Institute of AREI ensuring long-term cooperation between plant breeders and seed producers. Besides that, seed material of popular cereal varieties has been reproduced in farm and distributed to organic farmers in Latvia and European countries. Not everyone seed lot covers the high-quality requirements for certified seed. In such cases the part of the grain has been used for food. They reveal that it isn't so difficult to grow organic seed material. The challenge is harvesting and preparation of the seed material according to the certification requirements. It's more complicated and expensive for organic production.

Organic farm and bread bakery **"Ķelmēni"** is growing grain for bread baking by themselves. "Ķelmēni" produces traditionally baked organic rye bread. The bread baking recipe has been created by the family. However, very important for this farm is to provide full-cycle and waste-free production. The farm offers organic feed grain as by- product of baking process for local organic cattle farms. Hosts of bakery believe that certified seed material is very important factor affecting grain quality and also the quality of bread in the further stages of production. Rye bread has the most complicated baking technology in general. Although different rye varieties have been tested by the owner, but Latvian winter rye variety 'Kaupo' so far has proven itself as the most suited for traditional bread. Representatives of the farm "Ķelmēni" are really confident and proud about their bread and continue to excite consumers without changing traditional methods to new ones.

The conference journey ended with a small organic family farm **"Ķeveiti"** that offers to visitors to taste true organic meal prepared on real fire. The farm is located far away from the crowded town life, hidden in Latvian landscape with sheep flocks at meadow's hillsides. Farmers are sure that working organically is the right way. It is proved by working and living organically in own organic farm and producing organic products. Sometimes visitors thought that living in countryside means doing nothing and relaxing, because benefits received from state has been enough to provide a comfortable life. But in countryside farming this is not the case. Farm management means hard work without holidays. Not only material resources are important, but also a lot of knowledge and understanding of animal care, crop growing and feed production. Everything requires a lot of understanding and patience from farmer. If farmers didn't learn it, they won't be able to support their family.

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Organic farm "Kalna Smīdes" – http://www.biomedus.lv/

Organic farm and bakery "Ķelmēni" – don't have web page, you will need to come for visit.

Organic farm "Ķeveiti" – https://www.keveiti.lv/

Organic farm “Indrāni”

1. Beautiful landscape of farm “Indrāni”

2. Organic raspberry jam

3. Organic linden flower and rye bread jellies

4. Conversation with Jānis from “Indrāni”

Organic farm “Kalna Smīdes”

5. Organic bee swarm winter location

6. Organic products from “Kalna Smīdes”

7. Conversation with Uģis from “Kalna Smītes” about organic winter variety ‘Kaupo’

8. Organic wheat stock in companies’ warehouse

Organic farm and bread bakery “Ķelmēni”

9. Conversation with Rūta from “Ķelmēni”

10. Scald making in wooden bowls

11. Loaf baking in very high temperature

12. Freshly baked bread, cut and packed

Organic farm “Ķeveiti”

13. Organic farm “Ķeveiti”

14. Conversation with Atis from “Ķeveiti”

15. Organic chicken and guinea fowl

16. Sheep flock at meadow’ hillside

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