PROJECT OUTCOMES
AND RESULTS

LIVESEED – BOOSTING ORGANIC SEED AND PLANT BREEDING ACROSS EUROPE

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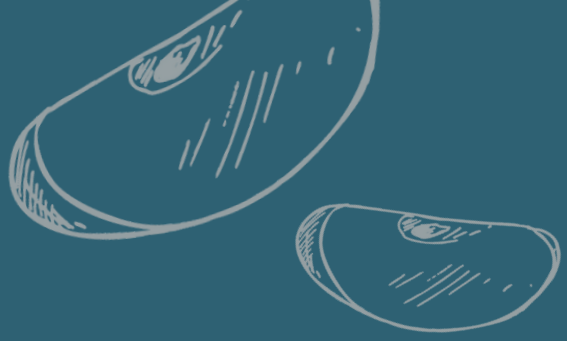
INTRODUCTION



As demand for organic food grows, so does the demand for organic seed and suited cultivars. To reach 100% use of organic seed adapted cultivars we need to overcome several challenges:

- technical difficulties in organic seed production
- inconsistent implementation of EU organic regulation
- lack of transparency regarding the availability and demand of organic seed
- insufficient organic breeding programs

The objective of LIVESEED is to improve the transparency and competitiveness of the organic seed and breeding sector and encourage greater use of organic seed.

LIVESEED strives to:

- Foster harmonised implementation of the EU organic regulation on organic seed
- Strengthen organic seed databases in the whole EU
- Investigate socio-economic aspects related to production and use of organic seed
- Improve availability and quality of organic seed
- Develop guidelines for organic cultivar testing and registration
- Develop innovative breeding approaches suited to organic farming
- Widen the choice of organic cultivars meeting the demand of farmers, processors, retailers and consumers
- Research five main crop categories (legumes, vegetables, fruit trees, cereals and fodder crops) considering different farming systems and pedoclimatic zones across Europe

The 4-year Horizon 2020 funded project (2017-2021) is coordinated by IFOAM Organics Europe and FiBL Switzerland and the multi-actor consortium consists of 37 partners and 14 third linked parties from 18 European countries.

This booklet provides an overview of the key current problems connected to organic seed production and use, LIVESEED's approach to investigate these problems, and selected project outcomes and key findings.

REGULATION & POLICY FRAMEWORK REGARDING PRODUCTION, USE, AND TRANSPARENCY OF ORGANIC SEED

There is a lack of transparency within the EU organic seed market and poor implementation of EU legislation requirements on a national level with regards to organic seed. According to the EU marketing requirements on Plant Reproductive Material, plant varieties for which organic seeds are on the market need to be registered and each country should maintain an up-to-date database of all available seeds, organic seed producers and production based on organic seeds. These databases are, however, not fully updated and sometimes do not even exist in certain EU countries, making it difficult to know what seeds are available. Furthermore, while there is data on the number of derogations granted in each country, detailed information on the number of producers that actually use organic seeds and the amount of production based on organic seeds are missing. This results in inadequate information on organic seed availability for producers but also for policymakers, making it difficult to arrive at evidence-based policies and solutions for incentivizing the use of organic seeds.

LIVESEED's approach

Transparency within the EU organic seed market and implementation of EU legislation requirements on a national level need to be improved. To understand how to best approach these, we first need sufficient information on the available seed. Thus, LIVESEED conducted comprehensive studies on the production and use of the organic seed, legal frameworks applied in the different EU Member States, the functionality of seed databases and the demand of seed suppliers and seed users. National seed expert groups on organic seed were initiated where they were missing, and best practice models were disseminated among countries. LIVESEED built an infrastructure (a router database) that facilitates information exchange on seeds at the EU level.

THE STATE OF ORGANIC SEED IN EUROPE

This booklet contains new information on the actual situation of organic seed production and use in Europe, collected using a range of research approaches. It covers the topic from four angles: farmers' perspectives (attitudes, influencing factors and knowledge) on organic seed availability, the national seed databases, and their roles in facilitating seed use, the derogation system and how it influences the market, and the seed suppliers' perspective on the organic seed market and the trends.

The booklet is based on a comparative review of the organic seed databases in 28 EU countries; an integrated analysis of national derogation reports; a survey among farmers on their use of organic seed and seed suppliers on trends in the offers of organic seed on the market. A quantitative model was also used to estimate the potential demand for organic seed in Europe based on the data collected.

MAIN OUTCOMES

- Seed companies consider the organic seed marking as growing, and they are willing to invest in organic seed, but lack data on the actual demand of organic seed in Europe, as well as a harmonized and clearly defined regulatory EU framework.
- Although the establishment of a computerized database is mandatory for all EU Member States, national databases greatly vary and lack harmonisation in terminology, architecture, and programming.
- The availability and quality of annual derogation reports of national authorities on the use of non-organic seed need harmonisation at the EU level. In general, there is more derogation requests for non-organic seed in vegetables compared to cereals.
- Farms in Central and Northern Europe use significantly more organic seed than those in Eastern and Southern Europe. In addition, farms marketing their products directly to consumers and organic shops have significantly higher organic seed rates than those selling through longer value chains (e.g. supermarkets, large retailers etc.).
- Only a small range of cultivars are available as organic seed. Actions are needed to increase the offer of locally adapted cultivars (in terms of range and quantity) and specific breeding for organic farming is required for arable, vegetable and fruit crops, involving stakeholders across the whole organic sector and long-term public and private investments.

The State of Organic Seed in Europe / FR

Factors Affecting the Use of Organic Seed by Organic Farmers in Europe

HOW TO IMPLEMENT THE ORGANIC REGULATION TO INCREASE PRODUCTION & USE OF ORGANIC SEED – POLICY RECOMMENDATIONS FOR NATIONAL AUTHORITIES

This booklet compiles specific recommendations and best practices to improve the use of organic seed and vegetative propagating material at national levels. It contains practical examples useful to national or regional authorities, certifiers, seed companies and farmers on these questions: “How to implement the organic regulation on organic seed at the national (regional) level?” and “How to stimulate organic seed production and use?”

The booklet is based on research on selected EU Member States’ implementation of the EU Organic Regulations with regards to organic seed, and covers policy measures to stimulate organic seed production and use (training, cultivar trials, subsidies, cleaning facilities), derogation rules, national annexes, equivalent cultivars, and the role and functioning of seed expert groups. Recommendations on improving the national databases and on handling other sources of organic seed (traditional varieties, farm-saved seed, organic heterogeneous materials) are also included.
The booklet is available in 11 languages.

MAIN OUTCOMES

- Mandatory training on organic seed production to receive a subsidy or become registered as a seed producer ensures the higher quality of organic seed produced.
- Organic cultivar trials are indispensable to develop lists of recommended cultivars for organic production in specific regions.
- The introduction of a National Annex is one measure Member States can use to stimulate the reduction of derogations in view of their phasing out in 2036.
- National Expert Groups on organic seed involving stakeholders from the supply chain can advise the national authorities on implementing the regulation on organic seed in the country and can facilitate a broader acceptance and faster implementation of the regulation itself.
- Next to improving the national databases, a common European router database can significantly lower the administrative burden for the organic seed suppliers in offering seeds on more than one national database through a single uniform portal.

The booklet available in eleven languages here (BG, EL, EE, EN, ES, HU, IT, LT, LV, PO, PT, RO)

LESSONS LEARNED FROM NATIONAL VISITS AND STAKEHOLDER WORKSHOPS IN THE EU

Project partners visited 10 selected EU countries during 2017-2018 with (i) a 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 involved. The selected countries were Bulgaria, Estonia, Greece, Hungary, Italy, Latvia, Lithuania, Poland, Romania, and Spain.

During the visits, competent authorities and stakeholders from the organic seed sector were interviewed. The main outcomes of the visits were summarized in "country reports," presenting the status quo for that given Member State. The reports' findings then were disseminated among a wide range of national stakeholders in 2019 during national workshops for discussions, as well as commitments were elaborated to overcome identified bottlenecks and possibilities for improvements regarding the production and the use of organic seeds at the national level.

MAIN OUTCOMES

- In several countries, there is a lot of uncertified seed on the market, especially from cereals. Farmers are in often the main producers of (organic) seed. In Southern Europe maintaining agrobiodiversity has more priority than organic seed.
- In most countries visited, the interpretation and the implementation of the derogation rules cause a high administrative burden (and thereby costs) for farmers and the competent authorities.
- The main obstacle found regarding the implementation of the derogation rules is that in most EU Member States visited, the approach as it has been applied so far has not encouraged the use of organic seed.
- National non-derogation lists, implemented in seven countries, has proven to be effective at increasing the production and use of organic seed, step by step, with the commitment of the stakeholders.
- In many countries across the European Union, organic seed databases do not meet the main goal: i.e., providing an up-to-date overview of the organic seed available on the market in that country. Seed, furthermore is often sold directly to farmers. Since the availability of organic seed on the database is the legal touchstone for granting derogations, a dysfunctional database can lead to unsubstantiated exemptions for the use of conventional seed.

National progress reports on the Production and Use of Organic Seed between 2017-2020

Reports with Policy Recommendations and Declarations of Organic Seed

Report on Political Obstacles and Bottlenecks on the Implementation of the Rules for Organic Seed in the Organic Regulation

North Western European Workshop

European Workshop on Organic Seed Production and Use

CREATING INCENTIVES FOR FARMERS TO USE ORGANIC SEED - BOTTLENECKS AND SUCCESS FACTORS IN 4 PILOT CASE STUDIES

Farmers' commitment to using organic seed can be influenced by organic seed availability for the varieties they need, by receiving a discount on the price or by a clear demand from traders, retailers, and wholesalers in addition to consumers. It is also important for them for the integrity of organic production or for meeting consumers' expectations. Such incentives to farmers have been experimented in different countries, to accelerate growth in their use of organic seed. Often these are done on a small scale in a specific supply chain with a limited set of crops.

This booklet presents examples of implementing such incentives in different EU countries: pre-financing organic seed through the value-chain (Italy), access to a specific variety requested by the market (Netherlands), expanding the range of cultivars adapted to organic and local conditions (Hungary), and improving seed quality (Romania).

MAIN OUTCOMES

- Incentives to motivate farmers to use organic seed can be economic, social, technical, ethical, and ecological in nature.
- In Italy, with the pre-financing initiative, the amount of organic durum wheat seed use among the cooperative's members has grown from 15% to 50% of the total potential seed demand.
- The Dutch pilot has shown that organic production of spinach seed is possible at excellent quality. The pilot will be a complete success if a premium price could also be achieved for the final product obtained with organic seed.
- The Hungarian pilot proved that emmer and einkorn landraces can be suitable for low-input production areas in Hungary. However, processing of the final product remains a bottleneck, especially if cleaning and dehulling the grain requires specialized equipment often lacking on the farms.
- A key success factor in the Romanian pilot is the close collaboration between cooperative members and the research institute NARDI on seed health.

EU ROUTER DATABASE CONNECTING NATIONAL ORGANIC SEED DATABASES

For the EU Member states, the establishment of a national database to list all offered organic seed and seed potatoes is mandatory. Article 48 of Regulation EC No 834/2007 describes the requirements of the national organic seed databases in detail. Any organic seed offer which has not been registered in the national organic seed databases shall be considered as "unavailable" and derogations on the use of untreated, conventional seed can be granted. The European Union set a deadline to phase out these erogations by 2036 (Regulation EC No 2018/848). Therefore, organic seed offers must be added to the national databases.

To aid seed suppliers in their entries of seed offers in different national databases through a single platform, as well as to help national authorities to evaluate offers from foreign seed suppliers, an EU Router Database was developed in LIVESEED that connects to national seed databases through API programming interfaces.

MAIN OUTCOMES

- The open-to public website offers information on registered seed suppliers, links to national organic seed databases, organic production regulations, as well as information to relevant publicly funded projects in the organic seed and breeding sector.
- The platform can grow to display information on organic cultivars, smart practises implemented at the national level, national derogation reports, national classifications of species/sub-species, as well as other relevant reports.
- Registered seed suppliers can upload information on their available organic seed offer and indicate in which country this offer can be delivered. Designated national authorities or bodies can evaluate the offer and decide on the acceptance or rejections through the platform.
- The database significantly reduces the administrative burdens for seed suppliers and removes
- language barriers of national databases. User guides in 21 EU languages will be available.
- The database will increase the transparency on organic seed availability for the market and for the policymakers in the EU.

European Router Database for Organic Seed

Guide for Authorities

Guide for Seed Suppliers

Trainings on the EU Router Database

- Training for national authorities on the EU Router Database (26 April 2021): Presentation – Webinar
- Training for seed suppliers and seed producers on the EU Router Database (28 April 2021): Presentation – Webinar
- [German] Training for seed suppliers and seed producers on the EU Router Database (5 May 2021): Presentation – Webinar

IMPROVING CULTIVAR TESTING, SEED MULTIPLICATION & HEALTH FOR HIGH QUALITY SEEDS FOR THE ORGANIC SECTOR

It is crucial that organic farmers possess knowledge about cultivar performance under organic growing conditions to determine which cultivars are the best suited for their context. As there are substantial differences in cultivar rankings between organic and conventional cultivar testing as well as between countries, systematic cultivar testing under organic agriculture needs to be installed across Europe. Criteria that are crucial for organic agriculture are often not included in the cultivar testing protocols, which are developed for conventional agriculture. Adapted guidelines for cultivar testing for organic agriculture are largely lacking. This leads to problems with identifying suitable cultivars and with the registration of new organic cultivars and creates obstacles to widening the pool of high-quality seeds available for the organic market. There is, furthermore, a need for peer to peer learning in seed multiplication and more research concerning seed health issues.

LIVESEED's approach

LIVESEED developed and improved the efficiency of cultivar testing models under organic farming for the identification of suited cultivars. The project developed adjusted protocols for DUS and VCU examination suited for the official variety registration and new descriptors for the marketing of heterogeneous populations. Furthermore, LIVESEED fostered knowledge exchange through cross-visits and local demonstration events across Europe on seed propagation and investigated novel seed health strategies and technologies focusing on the vitality of organic seed.

OVERVIEW OF THE ORGANIZATIONAL MODELS OF CULTIVAR TRIALS FOR ORGANIC AGRICULTURE IN SOME KEY EU COUNTRIES

Cultivar trials are an important way to evaluate the suitability of existing varieties (conventional, organic, landraces, heirloom, etc.) for organic farming, and are a necessary step in plant breeding and variety registration. It is also essential that varieties are tested on-farm in different climatic regions as this gives more accurate and realistic variety performance assessment. In this report we present how certain countries implemented specific organic VCU (Value for Cultivation) testing to motivate other Member States to find inspiration in these examples.

The evaluation of different organic variety trials for breeding and post-registration as well as VCU across 15 EU countries (for arable incl. forage, vegetable, and fruit crops) is presented through 4 main criteria (trial setup, organizational model, dissemination of results and financial model). Institutes or initiatives organize cultivar trials depending on different socio-economic conditions. A SWOT analysis of different organizational models give better understanding of pros and cons of the different systems and show necessary infrastructure for different models.

MAIN OUTCOMES

- Organizational models of cultivar trial networks are ranging from those that are mainly governmentally supported and involving researchers, others that have a strong engagement of breeders and seed companies, or are done within seed companies, to those that are running only when project financing is available or that are established by farmers and done on a voluntary basis.
- Organizational models of cultivar trials have quite complex nature and therefore, it is not possible to give a general recipe for establishing successful variety trial networks.
- Institutes or initiatives organize trials depending on different socio-economic conditions, such as financial possibilities, economic importance of the crop in the country, chain actors' engagements, organic sector development, existing trial infrastructure etc.

Full report

A TOOLBOX FOR IDENTIFICATION AND DESCRIPTION OF ORGANIC HETEROGENEOUS MATERIAL (OHM)

To improve the effectiveness of the Organic sector, the New Organic Regulation 2018/848/EU endeavours to make the seed legislation more inclusive of cultivars that could benefit organic production. In this context Organic Heterogeneous Material (OHM) is introduced, which will enable commercialization of genetically heterogeneous cultivars produced under organic conditions.

The report aids the interpretation and implementation of the New Organic Regulation text and aims at being considered as a scientific input in the discussions of the associated delegated acts relating to OHM. It provides, first, a summary of experiences of the temporary experiment 2014/150/EU allowing the marketing of seed of heterogeneous populations of wheat, barley, oats and maize pursuant to Council Directive 66/402/EEC. Second, it clarifies the general requirements of OHM in terms of development and production compliant with organic principles and the non-applicability of Intellectual Property Rights. Third, it proposes and describes five key tools for characterisation of OHM that can be used in the notification process alongside a proposed framework to forecast scenarios of application of these tools to three categories: Farmers' Selections, Dynamic Populations and Composite Cross Populations (CCPs).

MAIN OUTCOMES

- The provision of Article 3 (18) of the Organic Regulation will allow the sale and use of Organic Heterogeneous Material (OHM), leading to a wider variety of cultivars available to the market.
- Farmers' Selections, Dynamic Populations and Composite Cross Populations (CCPs) will require different approaches to their notification processed by national authorities.
- Origin, region of cultivation, breeding method, phenotypic traits and traceability can be used as tools with varying relevance for certification and description of the three proposed categories.
- Case studies to understand the performance of these cultivars over space and time will be required.

Experiences from marketing heterogeneous populations in the EU

Proposal for a toolbox for identification and description of organic heterogeneous material

OPTIMIZED CULTIVAR TRIALS FOR ORGANIC AGRICULTURE

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 the information required by farmers to choose the cultivars best suited for their needs. This report aims to foster the development of these networks by proving key resources to set them up and/or to optimize them. The report provides guidelines to scope, set-up and manage networks for cultivar testing under organic conditions, to the benefit of the whole organic sector, as well as non-organic low input farming.

MAIN OUTCOMES

- Applying the "Define – Knowledge – Concept – Project" (DKCP) process based on the Concept-Knowledge (C-K) theory, the key concept of "frugal innovation" was developed guiding and supporting the development of a strategy that evaluates the objectives and constraints for on-farm trials;
- According to the objectives and constraints of involved stakeholders, this report proposes innovative methodologies to develop appropriate socio-technical organisations (e.g., on-farm, decentralised, and multi-actors, low-budget), together with adapted experimental design, data collection, and statistical methods for reliable results.
- Crop-specific protocols with relevant (combination of) traits to assess the cultivars' quantitative and qualitative performances, including agroecosystem, will be provided for cereals (wheat and barley), faba bean, carrot, cabbages, potato, tomato, and apples.

Frugal, multi-actor and decentralised cultivar evaluation models for organic agriculture

Guidelines for organic on-farm cultivar trials: EN, FR, IT, NL, PT, RO

Technical booklet for trial facilitators

GUIDELINES FOR ADJUSTED PROCEDURES FOR THE MARKETING OF ORGANIC VARIETIES

In the new Organic Regulation EU 848/2018 two new categories of plant reproductive material (organic heterogeneous material and organic variety) was introduced in order to embrace diversity in cultivars from organic plant breeding. In the existing testing regime, however, organic breeders face challenges when the level of genetic diversity is too high in cultivars. The new category of organic heterogeneous material is not intended to be uniform or stable, and cannot meet the requirements of Distinctness, Uniformity, and Stability (DUS) in the existing testing system. Organic Varieties are defined as plant varieties according to EU 2100/94 and thus "considered as a unit with regard to its suitability for being propagated unchanged". Users are thus guaranteed a variety that can be described and whose characteristics of interest are stable over time. When VCU is relevant (agricultural crops), performance is also guaranteed. The Commission has introduced a seven-year temporary experiment to describe the characteristics of organic varieties and to determine the production and marketing conditions of organic varieties. This LIVESEED report gives recommendations, criteria, procedures, and decisional guidelines to make certified production and marketing of "organic plant reproductive material", and recommendations for the upcoming temporary experiment on organic varieties as laid out in the new organic regulation.

MAIN OUTCOMES

- A survey among organic breeding companies collected information on challenges experienced with the registration of organic varieties (both DUS and VCU testing) and provided suggestions for improvements in protocols.
- LIVESEED recommends that the temporary experiment should cover criteria for description of organic varieties and determine the conditions for the production and marketing. It should include both DUS and VCU, including the use of adapted DUS and VCU protocols for relevant species. Specialized crops with only limited marked share may also be relevant.
- Temporary experiment should use existing DUS trial sites, and in some cases, observations could be carried out at breeder´s locations. For VCU trials it would be valuable to test if new low-cost organization models for organic variety trials proposed in LIVESEED can be used to supplement official VCU-testing of organic varieties.
- Different types of cultivars between the categories of OHM and organic varieties should be tested in DUS tests to define methods to distinguish between them.
- Besides adjustment for DUS and VCU the temporary experiment could also embrace experiences on how to ease the procedure of registration for some species (e.g., apple).

Guidelines for adapted DUS and VCU testing of organic varieties

INVENTORY OF SCIENTIFIC, TECHNOLOGICAL AND LEGAL MEASURES TO IMPROVE SEED HEALTH AND SEED QUALITY IN EUROPEAN ORGANIC FARMING, AND AN INTEGRATED STRATEGY TO OPTIMISE ORGANIC SEED HEALTH AND QUALITY

The use of healthy seeds or vegetative propagation material forms the basis of sustainable crop production. Unfortunately, organic seed quality is not always optimal. One reason can be pathogens infecting the mother plants, from which some can travel in or on the seeds to the next generation. Seed production in many cases like vegetables or biennial species takes longer than crop harvest used for food or feed production, mother plants are exposed longer to pressure from weeds, pests, diseases, and abiotic stress. Organic seed health is based on a multitude of factors and cannot simply be managed through one-size-fits-all solutions such as curative seed treatments.

MAIN OUTCOMES

- This report presents an inventory of seed health and seed quality related issues in European organic farming.
- Discusses measures that can improve organic seed quality including topics of seed production conditions, seed maturity, the seed microbiome, the effects of seed sanitation treatments, the application of biologicals, and the use of disease-resistant varieties.
- Describes case studies on seed health issues, including Alternaria sp. on Carrot, Bunt on winter bread wheat, and other studies on Alfalfa, Potato and Pea.
- A list of recommended priority areas for future research as well as a recommended holistic seed health strategy that takes into account the entire seed production cycle from seed vigour, plant and seed microbiome, plant establishment and farming management, seed maturity, drying, processing and storage is presented.

Organic seed health. An inventory of issues and a report on case studies

Need for a new seed health strategy

ORGANIC FARM-KNOWLEDGE PLATFORM AND A NEW SECTION DEDICATED TO ORGANIC SEED

The Organic Farm Knowledge platform provides access to a wide range of practical tools and resources about organic farming and serves as a virtual meeting place for cross-border learning. The platform promotes the exchange of knowledge among farmers, farm advisers, and scientists, with the aim of increasing productivity and quality in organic farming across Europe. Within the LIVESEED project, the platform was extended to include knowledge on organic seeds and breeding.

Articles, datasheets, leaflets, guidelines, practice abstracts and videos are available in four sub-categories (seed production, plant breeding and variety trial, seed quality, and economics and regulation of organic seed) for practitioners.

MAIN OUTCOMES

- Horizon 2020 funded EU projects contribute to the platform, including LIVESEED.
- 49 practical tools and practice abstracts have been uploaded to the organic seed section from LIVESEED.
- The platform can transfer tools directly from Organic EPrints.
- The platform contains information in the EU Member States' languages and supports an automated translation of both website menus and tools' descriptions.
- An advanced search function facilitates easy access to tools.

Organic Farm-knowledge Platform

OUTCOMES OF CROSS-VISITS ON ORGANIC SEED PRODUCTION

In the framework of the LIVESEED project, four cross visits were organised to demonstrate smart practices and to promote the exchange of knowledge among practitioners, with the aim to increase productivity and quality in organic seed production. The visits were organised in France (2018), Italy (2019), Netherlands (2019) and in Germany and Switzerland (2020) for agricultural trainers, farm advisors, and key stakeholders from countries where organic seed production is less advanced in Europe.

The cross visits offered a valuable wealth of knowledge on practical and technical issues of organic seed production for cereals, vegetable, potato seed and fruit propagation. These were captured in detailed reports, videos, Practice Abstracts, a booklet, and magazine articles. A report summarizing the lessons learned concerning the organisational and methodological issues related to cross visits was also produced.

MAIN OUTCOMES

- Cross-visits remain essential tools for knowledge exchange and for building of regional or European networks of expertise.
- The knowledge gained through the visits was exploited by the participants through knowledge transfer, everyday practice, training materials, demonstrations at farmers field days and resulted in new practices/methods/processes/innovations as well as discussions in round tables/expert groups in Hungary, Bulgaria, Romania, Poland, Portugal, Spain, Greece, Latvia, Austria, and France.
- The applied methodology developed in the framework of the AgriSpin project offered valuable elements, yet it is important that for multi-actor groups the methodology is adapted according to the group and the context, and that the participant selection and program development are iterative processes.

Reports on the outcomes of the cross-visits on organic seed production

Success stories on organic seed production & breeding - EN / IT / RO / ES

INNOVATIVE BREEDING STRATEGIES FOR ORGANIC AGRICULTURE

There are still considerable gaps in the assortment of suitable cultivars for organic farming in Europe. One of the most important variety characteristics for organic farmers is yield stability over years. As the organic sector has fewer means to correct unfavorable weather and other growing conditions, it is important that varieties are resilient enough to secure yields under a variety of conditions. There is a need to better understand the concept of resilience and how that can be transformed into breeding objectives. One objective can be to develop plant traits for improved resilience. Improved disease resistance is one aspect that has not been fully addressed in breeding yet. The relationship between yield, resilience and product quality is also not yet well understood. Combining these different traits in new cultivars for organic agriculture is one of the biggest challenges in breeding. Another objective can be to develop new breeding strategies based on more diversity such as the so-called Composite Cross Populations and variety mixtures. Farmers also face problems when trying to find the best combinations of varieties as breeding has not yet addressed combinability of varieties to optimize the benefit of synergies and plant-plant interactions.

LIVESEED's approach

LIVESEED provided inspiring guiding principles (concepts, scientific hypothesis, and strategies) to support the diversity of breeding activities to ensure that the needs of the organic sector are met. Moreover, breeding pathways were exploited to enhance resilience at the farm system level, considering the holistic dimension of organic systems. The project developed novel breeding concepts that combine participatory approaches with modern breeding tools considering different socio-economic contexts. Exciting scientific discoveries on the complex interface of the plant with the living microbiome in and around the plant were analyzed for their potential exploitation in breeding programs for organic and low input breeding.

STATE OF THE ART OF EXISTING ORGANIC BREEDING INITIATIVES

Despite the growing number of organic breeding initiatives, as a whole, organic breeding is still relatively marginal compared to conventional breeding. To strengthen organic breeding, it is a first step to assess the current state of existing initiatives, programs, and networks.

In LIVESEED, nighty-nine such initiatives from Europe and the USA were collected, described, and surveyed for their activities, types of breeding approach, crops, and interests in collaboration with other initiatives. The overview of the initiatives can be found in its Annex I.

MAIN OUTCOMES

- The nighty-nine initiatives collected include commercial breeding enterprises, SMEs, non-profits, farmer breeders, universities, and other public institutions.
- The initiatives cover a wide range of crops, with a strong focus on cereals, grain legumes and vegetables.
- Initiatives are interested in collaboration in breeding mostly in cereals, grain legumes, vegetables, and fruits.
- Many initiatives are interested in multiple different approaches of collaboration, including setting up initiatives for the future.

State of the art of existing breeding initiatives & actions planned to strengthen collaborations

PRIORITY SETTING OF RESEARCH NEEDS FOR ORGANIC PLANT BREEDING AND SELECTION METHODS BY FORMAL AND INFORMAL BREEDERS INVOLVED IN BREEDING FOR ORGANIC FARMING SYSTEMS

Organic plant breeding requires innovative breeding concepts and approaches dealing not only with technical breeding aspects, but also with broader sustainability aspects (socio-economic, environmental, climatic, and ethical factors). Following the IFOAM principles, breeders need to produce high-yielding, healthy, nutritious, resource-efficient cultivars that are climate-robust, culturally acceptable and contribute to ecosystem services, i.e. are ecologically and societally resilient.

To understand how these concepts and approaches benefit organic agriculture, a concept of a systems-based breeding approach was developed (Lammerts van Bueren et al., 2018), concluding that only such systems-based breeding approach can achieve all relevant sustainability targets: food security, safety, and quality; food and seed sovereignty; social justice; agrobiodiversity; ecosystem services; and climate robustness.

At a workshop with stakeholders, this concept was discussed to develop a common future vision and paradigm change for a more integrated, systems-based breeding.

MAIN OUTCOMES

- The systems-breeding approach proposes an integration of four paradigmatic orientations that currently co-exist: community-based breeding, ecosystem-based breeding, trait-based breeding, and corporate-based breeding.
- Twelve key elements of the concept were identified: corporate social responsibility, circular economy & true cost accounting, fair & green policy, knowledge development and integration, breeding strategies and tools, entrepreneurship, food security, safety & quality, food & seed sovereignty, social justice, agrobiodiversity, ecosystem services, and climate robustness.
- Stakeholders collected 85 solutions, 68 obstacles, and 39 examples for systems-based breeding in categories of market and industry, policy and governance, science and technology, and societal and cultural norms and values.
- The ways forward include the re-thinking the financing models of plant breeding, as well as the relationships within the value chain around organic plant breeding.

Discussions on new concepts and strategies for organic plant breeding

Towards resilience through systems-based plant breeding

BREEDING GAPS AND KEY FACTORS FOR STRENGTHENING SMALL BREEDING INITIATIVES IN WHITE LUPIN, BRASSICAS, APPLE, WINTER WHEAT AND TOMATO

There is a remarkable lack of organic seeds and/or varieties specifically adapted to low-input and organic farming in Europe. LIVESEED explored case studies to determine the most important gaps and key factors which are limiting the availability of varieties adapted to low input/organic farming. Then proposed solutions and alternatives for organic breeding networks to develop, reinforce or support small organic breeding initiatives in Europe. Project partners worked with several representative species as case studies for building interconnected organic breeding initiatives, and by doing so, to have a more comprehensive understanding of socio-cultural, economic, and technical factors that are important to mitigate the breeding gaps in these crops and to identify the most important key factors the stimulate the development of new initiatives.

MAIN OUTCOMES

- As the five case studies cover a broad range of annual, perennial, self-pollinating, and outcrossing species as well as different goals and approaches they can serve as a blueprint to transfer to other crops and agro-climatic regions.
- Before starting new initiatives for other crops, there should be thorough analysis to define market demand, existing gaps, and how the case study is embedded in the overall framework with respect to science and technology, market, society, norms, and regulations. A collaboration can result in a common toolbox of approaches, methods, improved breeding material, extended organic testing networks and eventually improved organic cultivars for farmers.
- It is important that the goal of the breeding network meets the demand of the market. Therefore, it is crucial to integrate value chain partners and engage them as early as possible. This involves not only farmers who buy the seed, but also food processors, traders, and consumers.
- Key factors influencing collaboration between breeding initiatives are the crops themselves, the stakeholders involved, the economic, regulatory, and societal framework in the respective countries, and available funding resources.
- The status quo of existing organic breeding activities is vastly different for the crops: for major crops like wheat and tomato there are several organic breeding initiatives and more advanced knowledge on genetics and breeding tools (e.g. molecular markers), while Brassica vegetables, fruit breeding or lupin have received little attention in plant breeding in Europe. While for the organic lupin, Brassica and apple breeding it was more important to link actors across Europe to reach critical mass to enhance breeding progress, for wheat and tomato it was more important to start regional networks.

Report on breeding gaps and key factors for strengthening small breeding initiatives

Report on breeding activities of white lupin, cell fusion free brassica vegetables, apple, common bunt resistance in winter wheat and participatory tomato breeding

NOVEL BREEDING CONCEPTS AND STRATEGIES FOR ORGANIC AND LOW-INPUT FARMING SYSTEMS – FROM TRAIT BASED TO SYSTEM-BASED STRATEGIES

A review describing what organic breeding is about and how it can contribute to organic and sustainable agriculture in general, using new innovative perspectives from a systems-based approach. Such an approach is a holistic approach and helps to understand how various technical and socio-cultural aspects are interrelated. Specific challenges and examples important for organic agriculture and organic breeding were organised according to fourteen topics. For each of these topics, experiences from EU and national projects were complemented with information from literature and key experts in particular knowledge fields.

Together these fourteen topics describe and showcase how organic breeding can use and contribute to a holistic perspective in successful ways, e.g., that innovations in organic breeding are well connected with innovations in other knowledge fields (agro-ecology, micro-biology, weed and disease management, sociology, and economy via e.g., re-arrangements of the market, and law and governance such as developments on intellectual property rights). Opportunities, challenges, and recommendations for various stakeholders are described in the final discussion section.

MAIN OUTCOMES

- In the context of organic agriculture there is still much scope for improvement at various levels: at plant level, crop, or field level and at value chain or food system level – requires the integration of transdisciplinary knowledge.
- In terms of opportunities, new effective holistic breeding approaches and methods are to be further developed and to be scaled up, involving researchers and other value-chain actors. Common elements of these effective holistic breeding approaches are 1) collaborative approaches, e.g. working with farmers and the whole value chain, also in terms of financing; 2) benefiting from plant – microbe interactions; 3) benefiting from plant diversity in complex systems, and 4) decentralised evolutionary breeding approaches.
- A better understanding is needed on potential trade-offs between traits in plants, the potential of plant-microbe interactions, other forms of organising the value chain, and financing organic plant breeding.
- Policy makers in close collaboration with the value chain can develop enabling policy for new effective organic breeding approaches and methods. The first policy field to think of is the field of cultivar registration, enabling new organic approaches that take common heritage as a point of departure. Other policy fields could facilitate awareness raising on the benefits of organic breeding and organic agriculture.

ENHANCING RESILIENCE AT SYSTEMS LEVEL THROUGH BREEDING FOR DIVERSE CROPPING SYSTEMS

This report aims to explore breeding methodologies and statistical methods that allow to co-design approaches for optimizing annual crop mixtures (with a focus on cereals), perennial crop mixtures (with a focus on grass-legume mixtures) and the development of concepts for co-breeding of agroforestry cropping systems.

Altogether, 26 field trials carried out by 12 institutions in 10 different EU countries have been analysed in this document with regards to their applied breeding strategies, applied methodology, analysed traits, their multi-actor approaches, and their results and contribution to the diversification of cropping systems and the increase of resilience. Six potential overarching hypotheses and several additional, individual hypotheses were tested with these trials. The individual trials have been described in-depth in the trials' full reports in Annex I.

MAIN OUTCOMES

- Benefits of composite cross populations (CCPs) for resilience compared to cultivar mixtures and cultivars in single stands were proven for barley and winter wheat, especially if CCPs were developed under the same growing conditions as the target environment.
- The breeding for inter-specific diversity needs to be context-specific, both at the agro-climatic and value-chain level. When breeding for mixed cropping, it is necessary to evaluate both species in the mixed stand. The type of companion crop determines the crop phenotype to breed for. The specific advantages of crop mixtures might vary considerably between agroecological zones, as local stress factors might have a greater influence.
- Increasing diversity is particularly useful to improve resilience in stress prone conditions. In our experiments on winter wheat, the created genetic diversity enabled resilience for those populations. For barley and maize, diversity improved yield stability over environments. At the field level, improving resilience through crop mixtures proved more difficult compared to increasing intraspecific diversity.
- Breeding tools (like CCPs or DOPs developed in LIVESEED) were reported as materials that can be used easily for on-farm breeding, increasing the adaptability to a diversity of pedo-climatic conditions, and reducing the costs of breeding.
- Multi-actor approaches can help developing material better suited for the needs of the different actors with high adoption rate witha better distribution of the work.

IMPORTANCE OF THE HOLOBIONT AS POTENTIAL SELECTION TARGET TO IMPROVE RESILIENCE AND PRODUCT QUALITY

A report investigating the use of the holobiont as a plant concept hypothesis for managing the organic plant breeding and seed production. Like other eukaryotes, plants are now considered as co-evolved species assemblages or holobionts, consisting of bacterial, archaeal, fungal, and other eukaryotic species (Vandenkoornhuise et al, 2015). Several approaches already exist to combine phenotypical evaluation and microbiome analysis to better understand and pilot plant breeding. LIVESEED has introduced studies with microbiome data in four tasks considering plant health (pea), organic seed health strategy (carrot), plant adaptation in contrasted environment such as agroforestry or plant breeding strategies (tomato, maize). An integrative approach in which robustness of seeds/plants from peas and carrots are also evaluated thanks to research using calorespirometry. During LIVESEED workshops on breeding for beneficial plant–microbe interactions international researchers discussed the potential of breeding for the holobiont and LIVESEED results.

MAIN OUTCOMES

- Questions covered about seeds were: (1) can a more diverse microbiome give the seed more tolerance to soil-borne pathogens or pests? Do organic seeds have a more diverse microbiome? (2) Can the tolerance be due to the physiology of the seed or is it due to the seed microbiome aiding the high vigour seeds? Can the microbiome be deteriorated due to poor storage? Is it important to test the effect of ageing on the microbiome? (3) What is the effect of organic versus conventional seed production conditions on the diversity in the seed microbiome? Can we perform an integrative approach of seed vitality (AOX activity) and resilience assessments?
- Questions investigated plants' adaptation to growing conditions and plant health through microbiome evolution: (1) Can we observe the microbiome evolution through generations in seeds and roots for adaptation to agroforestry systems? (2) Is disease resistance expression within a range of genotype of peas, correlated with specific microbiome community when tested in infected and healthy/suppressive soils?
- Our conclusion and LIVESEED results fed into recommendations for organic plant breeding and seed production strategies and strengthen the biological foundations of organic agriculture principles.

Review paper on microbiome breeding

Implementing Plant-Microbe Interactions in Plant Breeding

Perspective paper on microbiome

Report on the holobiont as promising selection target to improve resilience and product quality

SOCIO-ECONOMIC ASPECTS OF ORGANIC BREEDING AND SEED PRODUCTION

Research on the organic farming and seed regulatory frameworks has concluded that the current regulatory system did not lead to significant improvements in the supply of organic seeds at the EU level and that the type of market significantly influences producers' choice of seeds and varieties. It is necessary to investigate the range of economic and social factors influencing the use of organic versus non-organic seed from a market point of view, to analyze business and governance models and to explore financial incentives that might boost the organic seed sector. Some EU countries were able to develop a supply of organic seeds that meets national needs for some species, for other crops only a few new suitable varieties are available and the small organic breeding sector is not fully able to fill this gap. In addition, there is a strong informal seed sector addressing the issue through participatory breeding models that increase the diversity of seeds available, often using not-for-profit business models. Finally, organic seeds are more expensive than non-treated conventional seeds, creating an adverse incentive to use or develop organic seed production.

LIVESEED's approach

LIVESEED mapped the normative values of stakeholders, covering both the requirement for use of organic seed, and explored the impact of potential measures to improve the market and the regulatory arrangements. It analyzed the socio-economic aspect of organic seed markets, supply chains and business models to understand the reasons for market failure on organic seed markets and identified ways to overcome it, by describing and modelling the decision-making behavior of operators connected either directly or indirectly to organic seed markets. It assessed consumer preferences and acceptance of new breeding techniques and factors influencing the behavioral intentions, choices, and their level of acceptance.

FACTORS AFFECTING THE USE (OR NOT USE) OF ORGANIC SEED BY ORGANIC FARMERS IN EUROPE

A research report summarizing the results of an online survey conducted between November 2018 and June 2019, with a convenience sample of 839 organic farmers (of which 763 farmers completed the whole survey) in 17 European countries. The main aim of the survey was to identify factors encouraging or discouraging farmers to use organic seed. The survey also explored other issues relating to organic seed and breeding.

This is the first study investigating organic seed use from the farmers' point of view in several European countries that also considers all crop sectors.

MAIN OUTCOMES

- The main critical issue reported by the surveyed farmers is the availability of organic seed for the varieties they need. This is true regardless of the crop sector, but it is significantly less pronounced in Central and Northern European countries. Farmers reported a need for breeding for organic farming conditions, also to encourage organic seed use. This is true for the arable, vegetable and fruit sectors in all the study countries, but is less pronounced for the forage sector.
- Other differences between countries relate to the use of purchased organic seed versus farm-saved organic seed, with the highest share of farm-saved seed found in some Eastern and Mediterranean countries.
- Most surveyed farmers are satisfied with the quality of the organic seed used. About 15% of respondents stated to have germination problems and about 10% pests and disease problems.
- Farms selling through direct marketing to consumers and organic shops have a significantly higher rate of organic seed use than those who do not. Organic seed use in fruit-oriented farms was reported to be significantly lower than in arable and forage farms.

Report on relative importance of factors encouraging or discouraging farmers to use organic seed in organic supply chains

Summary article

THREE CROP CASE STUDIES INVESTIGATING THE SOCIO-ECONOMIC ASPECTS CHARACTERIZING THE ORGANIC SEED AND BREEDING SECTOR IN EUROPE

A research report exploring the status quo and regulatory regime for organic seed in arable, horticulture and forage crop sectors. It builds on literature, an analysis of different sectors, and 68 interviews with stakeholders of seed supply chains and organic seed production across 15 European countries.

Detailed analysis was carried out for three selected crops within each sector (focus crops): durum wheat, bread wheat and lupine for arable crops; carrot, cauliflower, and apple for horticultural crops and lucerne (syn. alfalfa), perennial ryegrass and white clover for forage crops. The report summarizes the general trends, regulatory and technical issues, seed multiplication aspects and breeding of these crop types.

MAIN OUTCOMES

- The organic arable seed sector is characterized by small to medium companies that multiply organic seed and sell through retailers or direct to farmers. Supply chain integration is common, and seed production may be outsourced to farmers or farmers' cooperatives.
- In the vegetable sector, a prominent level of integration between breeding and seed multiplication was observed, with larger companies producing seed from their own cultivars and breeding activities, investing in the breeding of crops that are expected to be profitable. There are smaller companies and/or initiatives involving farmers, which work with a wider range of crops and mostly with open-pollinated cultivars for organic.
- Organic seed production for forage crops occurs in Central and Northern Europe and interaction in the supply chain appears to only take place between seed companies and farmers.
- The three sectors have in common that they are characterized by a substantial increase in the organic land area in the last decade, leading to increased demand for organic seed. Yet,
- the untreated conventional seed is still commonly used for most crops and in all European regions, although some differences can be observed. The lack of effectiveness of the derogation regime is also suggested by the long-term trend in derogation in the three crop sectors.

Full report

DISSEMINATION MATERIALS

LIVESEED produced further useful dissemination materials for a diverse set of stakeholders. Scientific articles, book chapters, posters, abstracts, and conference proceedings were shared through open depositories. Several practical videos on organic seed management, seed health and storage, as well as on organic participatory breeding and testing, and videos targeting seed companies were produced. A map of existing fruit breeding initiatives in Europe and a list of organic seed databases were compiled. A list of cell-fusion free brassica varieties is now available (in EN, FR, IT, ES, DE). A website on the management of Tilletia caries was developed (FR, EN, HU). Six booklets from across all areas of work of the LIVESEED project are available, some in multiple languages. Over 50 additional guidelines and tools were also uploaded to the Organic Farm Knowledge Platform's Seed Section.

More results from the project:

LIVESEED website

LIVESEED on Organic EPrints

LIVESEED on Zenodo

LIVESEED on EIP-Agri

Organic Farm Knowledge Platform

LIVESEED on CORDIS

Website on Tilletia (common bunt) English / French / Hungarian / German

PROJECTOUTCOMES
AND RESULTS

LIVESEED – BOOSTING ORGANIC SEED AND PLANT BREEDING ACROSS EUROPE

LIVESEED

IFOAM ORGANICS EUROPE
FiBL Switzerland
AEGILOPS
AGES
Agrologica
Schweizerische Eidgenossenschaft
Confédération suisse
Confederazione Svizzera
Confederaziun svizra
Swiss Confederation
Federal Department of Economic Affairs, Education and Research EAER
Agroscope
de beersche hoeve
Institute of Agricultural Resources and Economics
Ökologische Saaten
bingenheimer saatgut
Bionext
BIOSELENA FOUNDATION FOR ORGANIC AGRICULTURE
Bundesverband Naturkost Naturwaren
Cultivari gGmbH Getreidezüchtungsforschung
crea
WAGENINGEN UNIVERSITY & RESEARCH
FELDSAATEN FREUDENBERGER
FiBL Germany
itab
ESAC ESCOLA SUPERIOR AGRÁRIA POLITÉCNICO DE COIMBRA
INRA SCIENCE & IMPACT
IUNG
SEMENTES VIVAS
Louis Bolk Instituut
ATK
ÖMKi
ORGANIC RESEARCH CENTRE ELM FARM
Rete Semi Rurali
sativa
SEGES
NARDI FUNDULEA
Ubios
UNIVERSIDADE DE ÉVORA
UNIVERSITÀ POLITECNICA DELLE MARCHE
UNIKASSEL VERSITÄT
VitaliS Organic Seeds
UNIVERSITAT POLITÈCNICA DE VALÈNCIA