Guidelines for organic on-farm cultivar trials

A practical guide for researchers and facilitators

LIVESEED

www.liveseed.eu

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Contents

Introduction

The crucial need for on-farm cultivar trials in the organic sector

Organic and low-input farming are a cornerstone of fair, healthy and environmentally-friendly food systems, as recognised by the European Commission in the EU Farm to Fork Strategy[1]. Organic systems tend to involve smaller farms than conventional operations, to be more diversified and multifunctional and to be managed with more sustainable practices, responding to the needs and preferences of consumers on local markets. Often, a greater variety of crops is grown over smaller areas. This further complicates the requirements for organic post-registration cultivar trials, as greater diversity of both species and cultivars should be tested.
Expanding the current infrastructure and logistics for organic post-registration trials would require large investments which are not justified by the current size of the organic market, even under EU policy support. Besides, on-station trials would be unlikely to provide realistic cultivar information for the varied range of environmental conditions experienced on organic, low input farms. However, more organic seed will have to be produced in the near future, calling for the registration of new varieties, as the derogations currently allowing organic farmers to use non-treated conventional seed (when no organic seed is available) will be completely phased out by 2036. Cost-effective, innovative and decentralized models for cultivar evaluation under organic conditions are thus urgently needed. The LIVESEED project offered the opportunity to co-design effective and innovative cultivar evaluation models, applicable even to those European countries with limited or no infrastructure in place. Such models are based on:

1. on-farm decentralised evaluation, by which a diversity of crops can be tested in a range of real-life conditions;
2. participatory approaches that make the most of farmers' knowledge of their environmental and value-chain needs and characteristics.

The models recognise that farming encompasses both social and technical dimensions, they therefore include a variety of stakeholders in multi-actor networks, applying frugal innovation principles[2] to address the issue of limited resources.

Cultivars for organic agriculture:

The new Organic Regulation EU 848/2018 recognizes the need for developing cultivars[3] suitable for organic agriculture. Such cultivars should have:

- enhanced genetic diversity
- disease resistance or tolerance
- adaptive potential to diverse local soil and climate conditions
- the ability to produce high-quality food to meet the expectations of organic consumers

[1] EU Farm to Fork strategy https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:52020DC0381
[2] "We define three criteria for frugal innovation: substantial cost reduction, concentration on core functionalities, and optimised performance level." (Weyrauch & Herstatt, 2017)
[3] The term (organic) cultivar is used as the generic term of reference for (organic) varieties, breeding lines, landraces, populations and 'heterogeneous cultivars' that fall into the category of Organic Heterogeneous Material (cf. the new Organic Regulation 2018/848/EU).

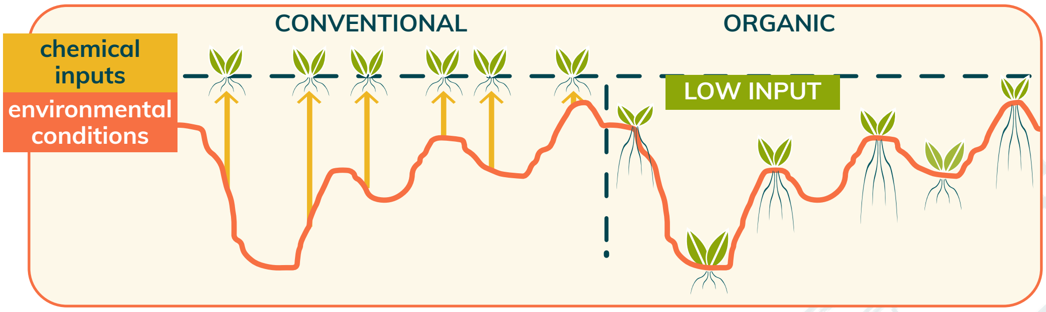
At the very heart of farming lie seed and plant reproductive material. These derive from cultivars which were bred to meet the needs of farmers and the value-chains in which they participate. Farmers can choose among cultivars that originate from different breeding strategies. Those most suited to organic farming pursue resilience to biotic and abiotic stresses through the maintenance of high levels of genetic heterogeneity in the resulting cultivars (Table 1).
However, most seed on the market derives from cultivars bred for the needs of conventional farming, centered on high productivity and on the use of

Procedure for registering a new variety:

Registration of a variety is required if it is to be put on the market. Registration implies that the variety is tested, both pre- and post-registration, for compliance to given criteria[4]: the DUS/UPOV requirements of Distinctness, Uniformity and Stability[5], and, for most agricultural crops, the Value for Cultivation and Use (VCU).
DUS and VCU trials are carried out under the responsibility of national registration bodies. Varieties that have passed the tests are registered in the official National Variety List and the EU 'Common catalogue of varieties of agricultural plant species', which is a precondition for the marketing of seed and, where relevant, for the attribution of Plant Breeders Rights (PBR), a form of Intellectual Property Right applicable to plant varieties.
However, for so-called conservation and amateur varieties, registration requirements are less strict and do not require DUS or VCU testing in light of the higher genetic diversity of these materials[6]. For Organic Heterogeneous Material (OHM) a simple notification process has been introduced by the new Organic Regulation 2018/848/EU and associated Delegated Acts[7]. As part of the Temporary Experiment on Organic Varieties (2022-2028), DUS testing and registration protocols adapted to the lesser uniformity of this material are being developed[8].

FIGURE 1. Genotype x Environment interactions

Growing conditions vary from place to place and from year to year.
Under conventional management, environmental variations are buffered by chemical inputs: plants benefit from uniform conditions and the same uniform variety can suit many different environments.
Under organic or low-input conditions, the plants need to make the most of the environments in all their complexity and variability. Genetically diverse plants can adapt to these environments and ensure stability of production. This can be achieved by deploying locally adapted varieties in different environments, or heterogeneous populations that can adapt/evolve to specific conditions (Adapted from P. Rivière "L'interaction génotype environnement GxE: sélection centralisée versus décentralisé" Licence CC BY NC SA 2015).



[4] EU plant propagation material marketing legislation https://ec.europa.eu/food/plant/plant_propagation_material/legislation/eu_marketing_requirements_en
[5] See https://www.upov.int/resource/en/dus_guidance.html
[6] EU conservation varieties derogations https://ec.europa.eu/food/plant/plant_propagation_material/legislation/conservation_varietes_en
[7] EU Organic regulation 2018/84/EU: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A32018R0848 and Delegated Acts C(2021)3163: https://ec.europa.eu/transparency/documents-register/detail?ref=C(2021)3163&lang=en
[8] See LIVESEED project deliverable: Guidelines for adapted DUS and VCU testing of organic varieties https://www.liveseed.eu/wp-content/uploads/2021/02/D2.4-LIVESEED-Guidelines-for-adapted-DUS-and-VCU-testing-of-organic-varietie.pdf

TABLE 1. Breeding strategy, official status and genetic diversity of different cultivar types available to organic farmers

Cultivar typology	Developed and Sourced	Legal requirements for marketing	Level of genetic diversity
Varieties	Conventional breeding	Marketing after registration (DUS, VCU) IPR/PBR applies	Very low
Varieties	Conventional breeding for organic farming	Marketing after registration (DUS, VCU) IPR/PBR applies	Very low
Organic varieties	Organic Plant Breeding (OPB). Organic breeding under organic conditions	Marketing after registration (adapted DUS & VCU). IPR/PBR under discussion	Medium
Conservation and amateur varieties (Landraces, local and heirloom varieties)	Traditional, locally adapted cultivars with historical/cultural value	Simplified registration process (No DUS/ VCU). Territorial and quantitative restrictions for seed production	High
Heterogeneous populations, OHM (dynamic mixtures, cross composite populations)	(Organic) breeding under organic or low-input conditions	Registration through notification process. Traceability of seed lots onus of the producer	Very high

synthetic inputs (i.e. pesticides, herbicides and fertilisers), and produced under large scale operations. The dominant agro-food system requires cultivars with a high degree of uniformity, to the extent that such criterion has become a pre-condition for registering varieties within the current seed market regulations.

Hence, conventional varieties rarely meet the needs of organic and low-input agriculture, where environmental variation and stressors such as pests and diseases cannot be mitigated by synthetic inputs. Under those conditions, farmers must rely on the crop's own disease and pest resistance, weed suppression capacity and stability of production under low or irregular levels of soil fertility (Figure 1). Uniformity becomes a shortcoming in this context, while genetic diversity provides an advantage.

When the use of external inputs is excluded or limited, as in organic systems, cultivar choice is a key crop-specific decision farmers can make to improve the outcome of their farming system. In order to make informed decisions, organic farmers need information about cultivar performance under organic conditions. Such information is generated through post-registration cultivar evaluation.

The current trial system predominantly carries out tests under 'conventional' conditions. This provides information of limited relevance to organic farmers since the performance of cultivars under conventional farming as compared to organic conditions may differ considerably.

To ensure that a given variety performs well under low input conditions and farmers are provided with quality information to make informed choices, it is essential that organic cultivars are tested under organic conditions (i.e. in organic plots and with organic methods). Only few EU countries, however, have the infrastructure for organic post-registration cultivar trials, and even then, only a few commercially relevant crop species are tested.

Setting up and optimising organic on-farm cultivar trials

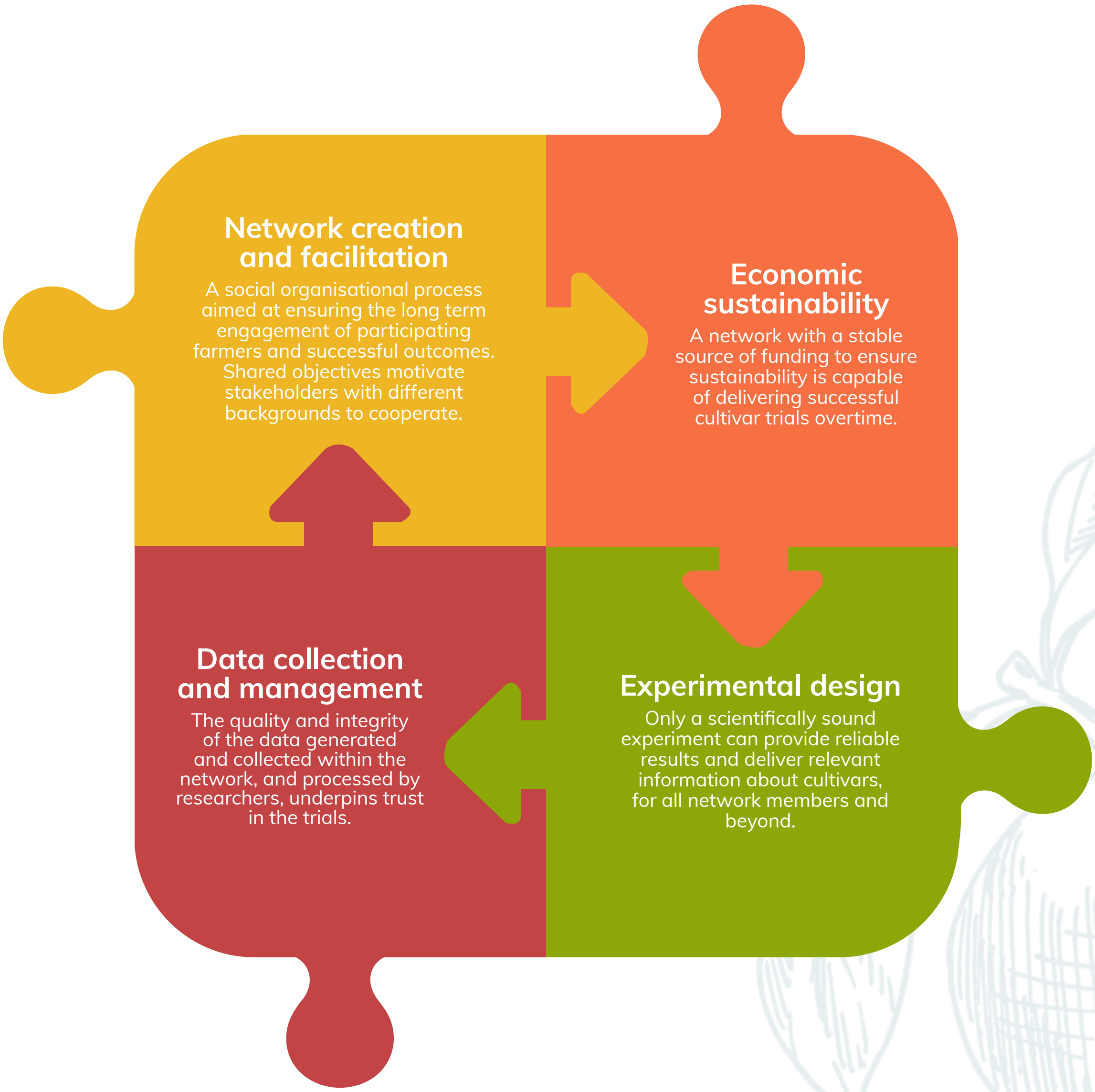
The “Frugal” strategy

Increased testing efforts for organic varieties call for a flexible, participatory, decentralized and low-cost structure, which builds on the capacities of farmers and food chain actors to meet a wide range of needs at different scales. Trials that meet these requirements are difficult to standardise. LIVESEED project partners have worked on a methodology to enable stakeholders to approach a programme of cultivar trials regardless of the specific situation and scale of the project (small to large, local to international).

The methodology tackles four key aspects of participatory on-farm trials described in the figure below, and offers a strategy for working through them.

The frugal strategy applies to each of the four aspects (more details in the following sections) and consists of three steps:

FIGURE 2. The four key aspects of participatory on-farm cultivar trials for organic and low input systems



Clearly defining the objectives in advance enables assessing and identifying any constraints which may hinder their achievement and which may arise from the specific circumstances of the trial (e.g. lack of specific resources or information). Using a constraint-focussed strategy from the start enables a multi-actor network to operate more effectively; indeed, once the constraints are clear, one can develop tailor-made methodologies that yield adequate results with the available resources.

TABLE 2. Examples of specific objectives, constraints and methods for each aspect of on-farm participatory trials

	General objectives	Constraints	Methods
Network facilitation and coordination	• Ensure active participation and achievement of agreed objectives	• Size of the network • Coordination burden • Communication skills and tools	• Participatory approaches • Facilitation skills and tools
Economic sustainability	• Self-sufficiency • Value creation • Viability in the long term	• Fixed costs • Labour costs	• Public support • User subscription models • Value-chain collaborations • Hybrid models
Experimental design	• Balance reduction in cost and effort with robustness and reliability of results	• Resources and information, farm size, machinery and resources	• A decision tree of experimental designs and analytical packages targeted to different contexts and constraints
Data quality management	• Relevance • Usability • Accessibility of the information	• Decentralised on farm collection vs number of research variables • Balance between farm-specific and common information	• Protocols for different data types, data documentation, data storage, data ownership and governance

Network facilitation and coordination

Network facilitation and coordination are cornerstones of participatory and decentralized on-farm cultivar testing. The facilitator's role is complex: he/she takes care that the distribution of roles and responsibilities within the network is well-balanced, ensures internal communication, makes sure the network's objectives are upheld, supports the dissemination of results back to the network, and encourages collective reflexivity. A complex set of soft and technical skills[9] is required: investing in a trained facilitator, or in training for those that are to become one, is a priority.

An issue often affecting facilitation in the context of participatory trials is the lack of skilled professionals, or of dedicated training for those who need to perform this role.

Depending on the skills available and the set-up of the trial network, the facilitation role can be staffed in a number of ways (e.g. a volunteer, an employee of a network partner, an external professional), each with different pros and cons.

TABLE 3. Some pros and cons of staffing choices for the facilitator's role

	Operational ability	*Participation and decentralisation*	*Financial resource intensity*	*Challenges*
Volunteer facilitation (e.g. association of volunteer citizens and farmers)	Limited	Strong	Low	• Volunteer exhaustion • Turnover and consequent loss of skills
Facilitation by paid staff (e.g. employee of a producers' group)	Strong to medium	Medium to low	Medium	• Agree on a common goal to mobilise diverse partners • Find the balance between objectives and resources
External facilitation (e.g. staff from a national or regional network)	Strong to medium	Low to very low	Strong to medium	• Distance from farms • Centralisation and poor dissemination

Enabling the network setup

In the context of multi-actor networks for post-registration cultivar trials, and depending on the objectives and the strategy of the trial, actors involved may include: farmers, seed companies, researchers, agricultural public bodies, breeders and value-chain actors (processors, retailers etc.).

In a wider citizen-science approach, students, chefs and the wider consumer community can participate. These actors should be involved in the management and be given operational roles: the facilitator will have to oversee the organisation and the clear definition of tasks, in order to minimise conflict.

[9] **Soft skills**, *such as sociability, active listening, autonomy, impartiality, ability to work in a team, mediation, conflict management, adaptation and flexibility.* **Technical skills**, *such as in participatory approaches and tools, ability to choose the most appropriate methods according to the contexts and objectives, communication and project management capacity. Both sets of skills are crucial for successful network facilitation.*

In some contexts, it may be difficult to get a research team on board to support the network with scientific methodologies and tools for trial design and accurate data management and analysis. The facilitator will have to take appropriate measures in these cases and, at times, self-train to fill the gaps or adapt the experimental design to his/her skills.
Network size impacts how activities are carried out. In particular, the level of participation is often inversely proportional to the size of the network. The facilitator will have to optimise effectiveness of the network by striking a balance between the minimum size necessary to achieve the goals and a maximum manageable size. For this task, one of the main challenges is to preserve the positive qualities of small, local networks, such as direct relationships and communication, regular meetings (some of which on farms) and buying-in to shared rules, even when the network extends further and requires a more hierarchical structure.

Network governance

Network governance will differ with the size and type of network, but it is essential to ensure trust and collaboration, to balance power relationships and resolve any conflicts that may arise.
One successful model of shared governance is the creation of a board representing the different network actors.
As cultivar testing through multi-actor networks is decentralised, the decision-making process must also be decentralised, while being based on shared goals. To ensure all actors buy into these, they need to be involved in the objective setting exercise and in the development of strategies; they also have to feel personally responsible for the success of the trial, regardless of their roles.

Enabling and stimulating active participation

With members dispersed geographically and engaged in different activities over a long period of time, it is essential to make sure that they are kept engaged.
Multi-actor endeavours are based on continuous and iterative processes of mutual learning, the results of which are in the process (such as trust developed among participants) as much as in the end products[10]. Therefore, carefully encouraging relationships and exchanges, best if supported by in-person meetings, is an important part of motivating and making sure everyone is aligned and clear on the state of the trial and where it is going. Workshops and field visits empower participants to express their views, sparking new ideas, and often revealing group dynamics that should be managed and directed towards the achievement of the shared objectives.
Network members may also be called to actively participate in decisions regarding technical and operational aspects of the trial, for instance to choose the best suited tools for gathering and sharing trial information (i.e. physical or digital fieldbook; spreadsheet or database), depending on the needs and abilities of the network. According to the choice made, any issue that might affect motivation and participation in the use of the tool needs to be addressed (e.g. uneasiness with technology). Including network members in methodological and operational decisions will boost motivation and prevent dropouts.

[10] *Serpolay, E., et. al., 2018. Toolkit to foster multi-actor research on agrobiodiversity. Available from: https://orgprints.org/38153/*

CASE STUDY 1

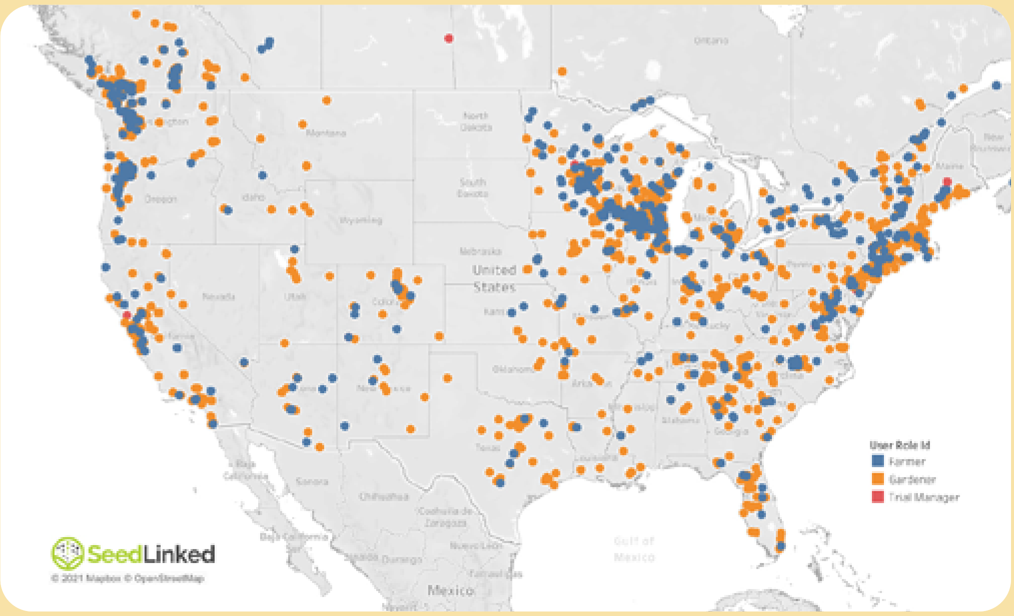
SEEDLINKED:
technology to support facilitation of a large network

Network size	
Costs	€
Research support required	

HIGHLIGHTS

- Decentralised and virtually self-run
- User friendly interface lowers barriers to entry and dropout rates
- Simple cultivar trial designs and dedicated tasting trial feature
- Instant data sharing and visual analytics

SeedLinked (*www.seedlinked.com*) is a crowdsourcing platform created to address the sharing of information about varieties suitable for organic and low-input agriculture. The platform is meant to connect researchers and breeding companies with farmers who seek varieties adapted to their farming context, as well as with consumers interested in food that is both tasty and traceable.
Like all crowdsourcing tools, SeedLinked is built to harness the wisdom of a vast network. Large networks are complex to manage and usually require a hierarchical structure. Crowdsourcing uses technology to turn such a structure upside down. Project quality control and participation motivators (i.e. live sharing of pictures and comments, chat facility, reward systems) are built into the platform. There are currently some limitations to the experimental designs available (only non replicated) and data collection features (only scoring), which should be addressed in updated versions of the SeedLinked platform and mobile app.



2021 SeedLinked Network (2700 growers)

Economic sustainability

Participatory cultivar testing requires continuity over several years, hence long-term investments. To ensure success, a suitable economic sustainability model for cost management and value creation has to be put in place.
Cultivar testing has related costs (e.g. facilitation, coordination, field trials, quality and organoleptic tests and physical facilities) that cannot be reduced below a certain threshold, even in the context of frugal on-farm trials.
The main income driver in a conventional breeding model is the acreage which will be occupied by a single variety; large cropping surfaces allow an efficient cost recovery from royalty fees (plant breeders' rights) and seed sales combined. The aim of Organic Plant Breeding (OPB) is on the contrary to breed for many different crops (including minor and neglected ones) and to produce highly diverse, locally adapted cultivars, each of which is likely to be grown on relatively small areas. Several OPB initiatives also reject the application of variety protection, since their vision is to maximise free access to cultivars.
From research across 15 countries in Europe conducted by the LIVESEED project, it emerged that the currently existing organic cultivar trials cover such costs with one or - more commonly - a combination of financing strategies[11].

ENGAGEMENT.BIOBREEDING EUROPE

Read more: *www.biobreeding.org*

Engagement.biobreeding Europe is an initiative dedicated to inspiring and engaging the whole organic value chain with organic breeding, in order to develop strategies to make organic plant breeding self-sustaining in Europe.

- Public financing (general operating grants or, more often, project-based funds);
- Private financing (operating funds of private agricultural organizations or funds from private donors and foundations);
- User financing (farmers memberships, voluntary work by different actors, breeders' and seed companies' contributions);
- Value-chain based financing (contributions by food manufacturers, wholesalers, retailers).

In order to successfully select for cultivars and traits that suit the needs of all actors, a promising funding strategy for organic on-farm trials would see all actors of the organic value-chain take a share of responsibility for organic breeding. A strategic solution could be the establishment of an overarching funding pool for the whole organic breeding sector. Within such a model, different actors of the downstream value-chain would be asked to contribute directly to the common challenge of providing farmers with adapted cultivars, as they also partake of the benefits.
Farmers are essential contributors of the financing strategy, as both co-creators and users of the value created by the cultivar trials. As the results from field-scale use of cultivars and the visibility of such results to farmers are important to the business model of breeders and seed producers, supplying seed and technical assistance for on-farm trials is in their interest too (see case study 1).

[11] Kovács, T., Pedersen, T. M., 2019. Overview on the current organizational models for cultivar testing for Organic Agriculture over some EU countries. Available from: https://orgprints.org/id/eprint/37818/

CASE STUDY 2

ON-FARM APPLE TRIALS IN SWITZERLAND:
a resource intensive project funded by stakeholders

Network size	
Costs	
Research support required	

HIGHLIGHTS

- Long-term investment ensured within the supply chain
- Combination of on-farm trials (by apple growers) and on-station trials (replicated and under two different pest management regimes)

Fruit breeding requires long-term trials (up to 10 years) and consequently implies high costs over time. As apple is the most produced fruit in Switzerland, retailer Coop, with its focus on organic food, has taken an active role and financially supported apple cultivar trials for a number of years, co-organized by organic control body BioSuisse and organic research institute FiBL.
To make available a broad range of apple varieties for the organic sector, matching the diverse agroecologies of organic farms, the initiative developed the innovative "flavour group concept": instead of being referred to by variety name, apples are marketed according to flavour groups, so that consumers do not get attached to a specific brand or variety, hence do not drive over-simplification of production systems, while satisfying their need to shop for apples they like.
The strong network established by FiBL involves, besides Coop, apple breeders, license holders, organic apple growers, storage keepers, and fruit tree nurseries. All partners collectively plan and organize trials and take care of disseminating the results.

Experimental design

Frugal, decentralized on-farm trials under organic conditions require adapted experimental designs. As previously described, the constraints affecting the working context drive the choice of the best suited methodological approach, including the experimental design. In this section we describe how to choose a design, and indicate which statistical analyses work best under each option.

Setting the objectives

The general objective of a cultivar trial is to assess "which cultivar(s) perform(s) well/best for one or more chosen traits, at farm or regional level".
This objective can be detailed on the basis of three main decisions:

- **Trial scale**
    - farm level - identify the best cultivars relevant to the very specific context of an individual farm (this format is more suitable for Participatory Plant Breeding projects than post-registration trials)
    - network level - identify the best cultivars relevant to a network of farms in a given region (we will focus on this format here)
- **Number of cultivars tested**
    - screening many cultivars for few key traits
    - testing few cultivars for many different traits
- **Choice of traits**
    - agronomic (e.g. yield, disease resistance)
    - qualitative (e.g. protein content, shape, colour)

In an organic cultivar trial conducted under a "frugal" framework, the size of the trial and the number of traits evaluated are often inversely correlated and have a direct effect on the number of cultivars included.
The final balance between desired objectives and trial implementation, which will determine the number of locations (network size), the number of cultivars tested and the traits of interest assessed, will emerge from the analysis of constraints.

Identifying the constraints

Constraints of particular relevance to post-registration on farm trials are:

- **#1 Resource availability.** Labour force and other resources to carry out the trials will impact its size: sowing and harvesting are particularly resource-intensive. It will also impact what data is collected.
- **#2 Number of locations.** This is directly related to the number of participants and depends on the coordination infrastructure. In decentralised evaluation, it is essential that real-life conditions are reproduced as far as possible, including the size and environmental conditions of the growing area, as well as the management practices utilised. A mix between research stations and experimental gardens and farms is a possible option.
- **#3 Seed availability (and related information).** Depending on the crop species, the required amount of seed varies: for example, less seed is needed for tomato trials than for wheat, and seed availability has an impact on the number of plots, their size, the number of replications, etc. Seed can be sourced from genetic resource centres, local farmers' groups such as community seed banks, or on the market (national or foreign). Collecting and screening available cultivar information in advance avoids wasting resources on less promising varieties[12].
- **#4 Number and size of plots per location.** These are directly correlated to the area available for

[12] Information can be retrieved through bibliographical research or by organising structured peer-to-peer exchanges where experienced farmer-breeders share their knowledge and know-how.

the trial and total seed availability. Farmers may not have a lot of space or time to devote to trials, especially when limited technical support is available. The size of the plots (and the number of locations) will also depend on the amount of available seed and the availability of farming equipment (such as sowing and harvesting machines). The latter is particularly relevant for cereals where it can be a major limiting factor.

- **#5 Duration of the trial.** Yearly variations and interactions between varieties and years are important factors, so trials over multiple years are preferable. However, limited resources may impose a shorter time frame. Results from one-year trials cannot lead to definitive results but can raise hypotheses for future years. A large number of locations can however provide enough information to compensate for a shorter duration of the trial.

CASE STUDY 3

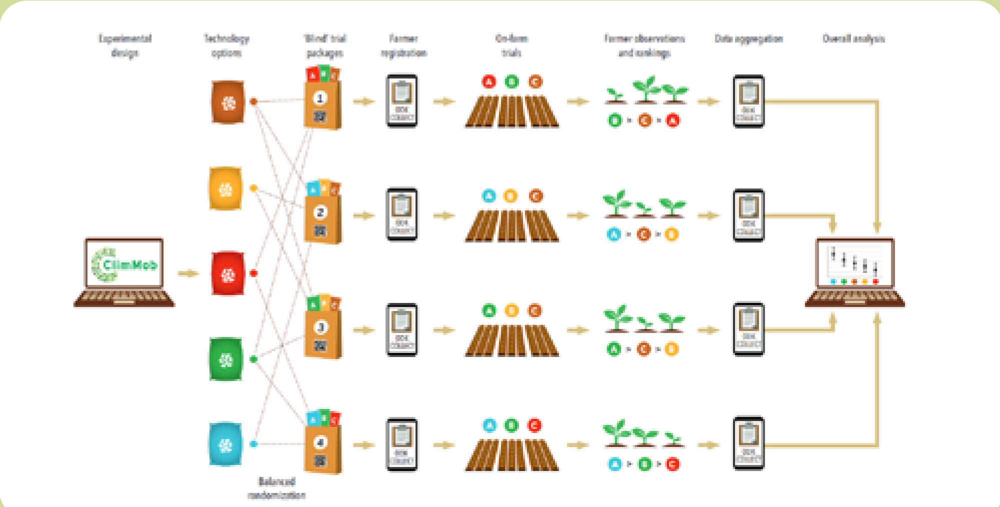
BEAN VARIETY TESTING IN NICARAGUA

Network size	● ● ○
Costs	€
Research support required	● ● ○

HIGHLIGHTS

- Trial setup & management through a dedicated online platform
- Data collection directly by farmer on Open Data Knowledge (ODK) app
- Ranking by farmers based on a key traits of interest (best/worst variety)

The initiative conducted TRICOT[13] trials for assessing bean varieties in farmers' fields. Participants were assigned a random combination of three bean varieties among those selected for the experiment. The trial was set up and managed using the Climmob platform (*https://climmob.net/blog/*) and communication with the project team occurred mostly through digital tools. Physical meetings were arranged at the start, during and at the end of the growing cycle (for distributing the seed and setting up the experiment, for collecting evaluation data, and for the final dissemination of results).



[13] *See Experimental design section page 16.*

Selecting the appropriate methodology

Based on the objectives and constraints identified, we propose the following decision tree as a tool for choosing the most appropriate experimental design for cultivar trials at network scale. The level of detail required to discuss each design cannot be exhausted in this booklet: the reader is encouraged to delve further in the technical aspects through the references available in the resources section.

The navigation within the tree is related to the objectives and constraints highlighted in the previous sections. The first two steps in the process are dependent on **network size** (1) and **number of cultivars** (2). These two factors determine which **experimental design** (3) is best suited for the trial. Depending on the trial's objectives (what kind of output data and information are desired) and constraints (how much data can be collected and by whom), a decision needs to be made in relation to **data collection and protocols** (4 - see the following chapter). Finally, for each experimental design, one or more statistical analyses will provide the desired results (5).

Traditionally, cultivar trials are conducted in a **Randomised Complete Block Design** (RCBD), partially or fully replicated. Data originating from this design is processed using the Analysis of Variance (ANOVA), followed by other statistical visual tests known as **Principal Component Analysis** (PCA). To better understand which cultivars showed an overall best performance and stability across locations, or within a single location, either the **Genotype + Genotype x Environment model** (GGE Biplot), or the **Additive Main Effects and Multiplicative Interaction** (AMMI) model can be used.

If farm sizes are a constraint, an alternative to the RCBD is the **Incomplete Block Design** (IBD), where a complete RCBD trial is split up in sub-blocks, which are assigned to participating farms. The number of farms will be dictated by the number of cultivars tested; each farm is assigned a block with no option to choose the cultivars within it. The statistical analysis used for this design is the **ANOVA Mixed Model.**

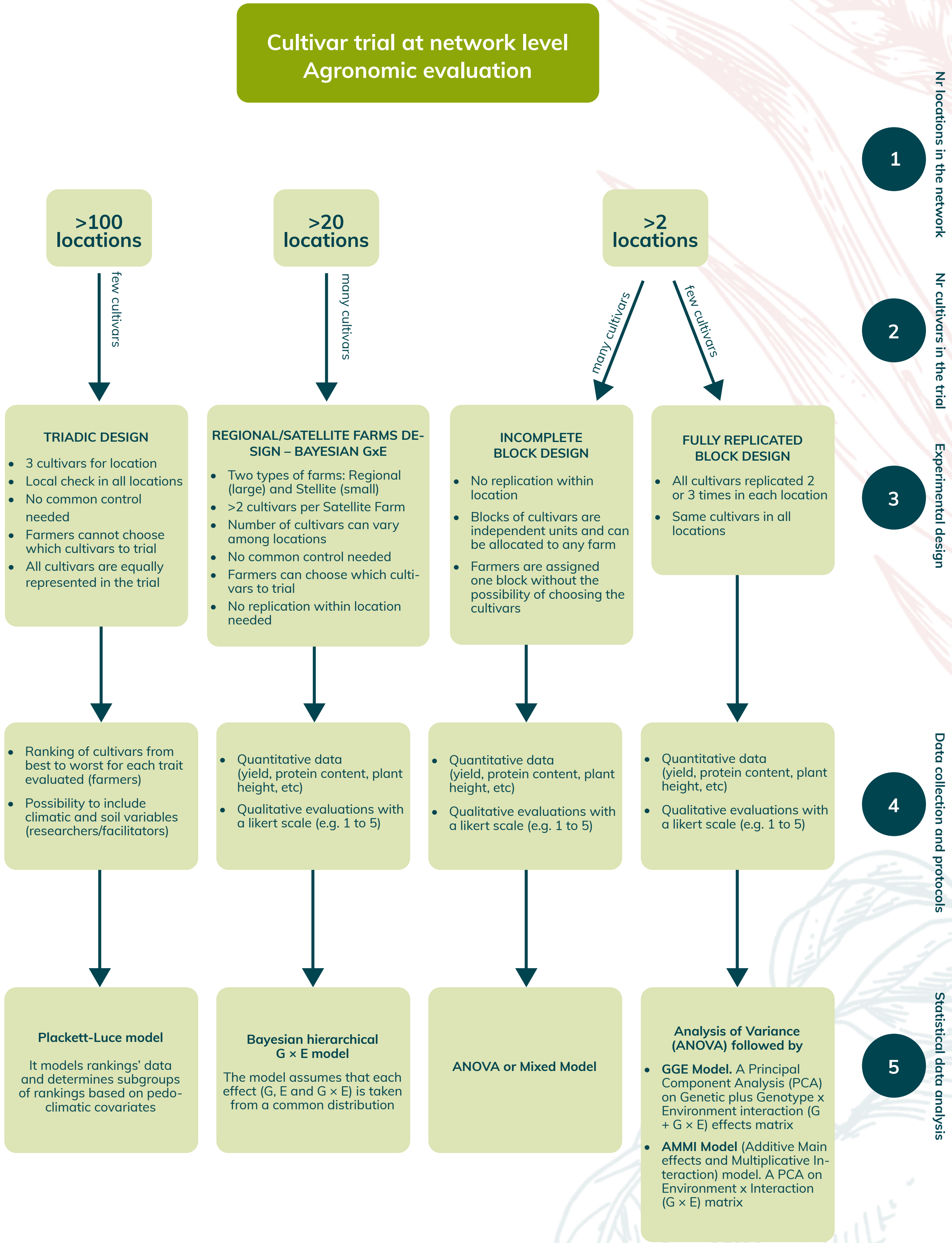
The quantity and quality of information generated with the RCBD design is considered by many the gold standard of cultivar trials, however its main downside for an organic "frugal" context, are the relatively large area required and the resource-intensive technical infrastructure needed for setting up the trials, and for collecting and managing data.

A more flexible alternative is represented by the Regional and Satellite farm design, whereby participants within the same trial network can choose which cultivars to test on their farm (from a minimum of 2 on a "satellite farm", to a maximum of the complete trial on a "regional farm"). The statistical analysis used here is **Bayesian Genotype x Environment model.** This system requires at least 20 farms in the network in order to generate meaningful information: replication of some popular cultivars across participating farms is recommended to increase precision.

For very large networks of 100 or more farms, a novel Citizen Science approach known as "Triadic Comparisons of Technologies" or **Tricot** can be successfully implemented. This experimental design assigns groups of 3 cultivars to each farm and relies on their ranking based on key traits (from best to worst). It has been successfully implemented in various contexts (see the Nicaragua bean and SeedLinked case studies) and be can easily managed remotely via dedicated apps[14], thus keeping facilitation and technical support to a minimum. Ranking analysis is performed with the **Plackett Luce model** and can be integrated with pedoclimatic variables (as covariates).

[14] *For more information visit: https://climmob.net/blog/*

FIGURE 3. Decision tree for choosing the best suited experimental design at network scale[15]



[15] *Adapted from Pierre Rivière (2019). Technical details available at https://priviere.github.io/PPBstats_book/ & Goldringer I., Rivière P., 2018. "Methods and Tools for decentralized on farm breeding". Booklet #3. Diversifood Project.*

CASE STUDY 4

ON-FARM TESTING FOR ORGANIC WHEAT VARIETIES IN THE UK

Network size	
Costs	€ €
Research support required	

HIGHLIGHTS

- The trial was run under real-world organic conditions, following local practices
- The varietal strips in each farm were harvested and sold or, on one farm, used within its home/small-scale milling operation
- Trial coordination and data collection were shared between the research team and local field agents

The initiative, funded by the LIVESEED project, aimed at optimising varietal choice of wheat cultivars for organic farms. It tested 11 wheat varieties, chosen using information from experimental organic plot variety trials and based on farmers' experience. The varieties were grown on 11 farms, in two blocks using different sowing and harrowing practices, with extensive support from the research team. A balanced incomplete block design was adopted for the first year, while in the second year the team chose an unbalanced incomplete block design. The common parameters were that all varieties were first drilled then harvested on the same day, and their management was identical at farm level; other than that, farmers were able to use their own farm machinery and follow their own management practices.

Data collection and management

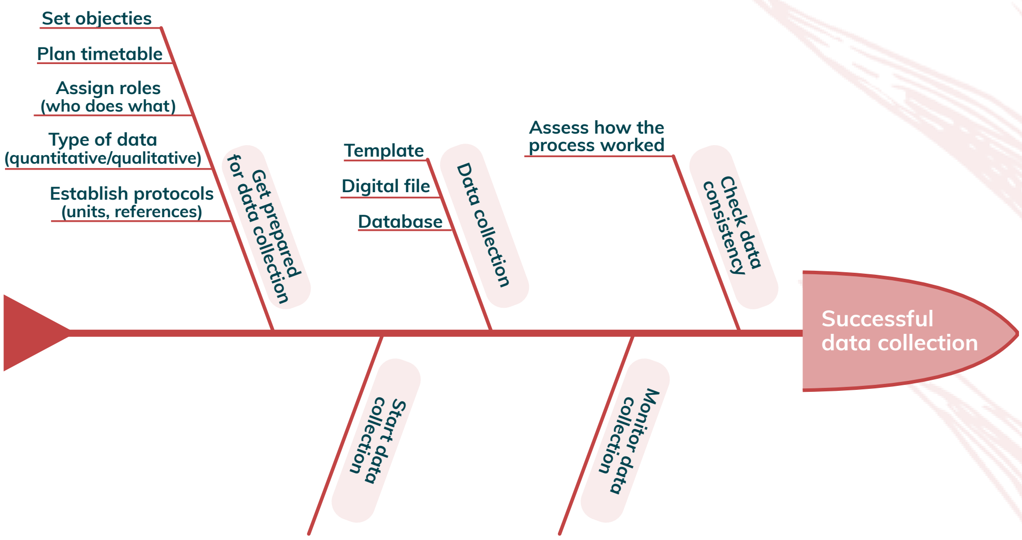
Data collection is the heart of a trial. It must produce the most trusted data given the constraints affecting each situation. In an on-farm participatory cultivar trial, where data collection is decentralised, the quality of data depends to a great extent on the clarity of the process and the trust among participants. It is therefore important to agree upon and clarify in advance both how measurements must be taken and how data will be managed.
The following aspects of data collection require special attention:

- The variables must be relevant, i.e. useful to reach the objectives of the trial
- The data must be measured accurately with rigorous methods and protocols
- The data must be processed and stored in a consistent way throughout the trial.

Regarding protocols, also with relation to potential constraints, it is essential to take into account:

- **Who collects the data**. Agreeing to protocols in advance with the collaboration of the farmers makes it clear whether data collection skills and workforce are covered or lacking.
- **Which data is collected**. Well-chosen, relevant variables

FIGURE 4. A useful workflow for high quality data collection[16]



can produce a comprehensive assessment of a cultivar's "value for cultivation", which in turn contributes to meaningful overall ranking of the trial entries. The measures to be taken should focus on the most important parameters in line with the trial's objectives agreed by all participants, and be easily measurable, regardless of the specific circumstances.

- **How data is collected**. In order to meet scientific standards, it is important to decide on appropriate measurement and evaluation protocols and to ensure all participants understand them.

The type of data collected in a trial depends on the traits being assessed. Combining various methods, it's possible to gather both data of scientific quality and access local and empirical knowledge, which is equally relevant for successful cultivar evaluation. The main methods to consider are:

- **Measuring (quantitative data).** A quantitative trait is measured for all the trial varieties, based on an agreed protocol and with an agreed method. This method provides the most homogeneous data (e.g. plant height, fruit weight, yield).
- **Scoring (visual evaluation).** Each trait of interest of each variety is rated based on agreed protocols, usually using a likert scale (e.g. from 1 to 5). Scoring for specific traits can be done according to a guide with pictures, colour charts or other media as a reference for different users (e.g. ground cover, leaf colour, lodging). Scoring for qualitative traits such as vigour, disease resistance, or general appearance, is usually done through visual evaluation, exploiting the experiential knowledge of participants.
- **Ranking**. Each variety is ranked based on the traits of interest or for an overall evaluation (i.e. which variety do I like the most? Order varieties from best to worst). This approach does not need detailed protocols or specialised tools.
- **Description (text)**. This method can be used to capture additional observations not foreseen in the protocol. It can be difficult to process because of its heterogeneous nature, however it can form the basis for useful and stimulating group discussions.

Besides the raw (or processed) data collected in the field, **trial metadata** need to be considered too. These

[16] *Based on Berti-Equille (2004) - see resources section.*

include trial information which is useful for contextualizing the results of the evaluation (location, soil type, meteorological records, crop rotation, fertilization, plot size, plant density, sowing dates, cultivar and seed lot information as well as personal details of those involved in the evaluation such as age, gender, and profession)[17].

Data storage also deserves a mention. Data deposited in an accessible and interoperable way makes analysis and information sharing easier. When organised and harmonised data is collected over time, a database is created that stakeholders can go back to, and find important historical information. Accessing data and visualising it interactively in a clear and coherent way can support evaluation and encourage participation.

Several databases to manage network trials exist such as SHiNeMaS[18], ClimMob (see case study 4) and SeedLinked (see case study 1).

SENSORY EVALUATIONS

Read more:
https://seedtokitchen.horticulture.wisc.edu/ and https://orgprints.org/id/eprint/38095/

The organoleptic and culinary qualities of organic varieties are of great importance to stakeholders in shorter food chains (i.e. bakers, consumers). Methodologies are being developed for the evaluation of those qualities alongside agronomic traits. As an example:

- *hedonic evaluation* to detect different preferences between products
- *napping test* to detect sensory differences between products

These can be linked to other databases for climate[19] or soil data[20] and combined with often more accurate information on local conditions provided by farmers.

FIELD BOOK:

An Open-Source Application for Field Data Collection on Android

A useful tool for cultivar trial data collection has been developed by Trevor W. Rife and Jesse A. Poland at Kansas State University. The app is open source and available free of charge on the Google Play store and other online repositories. The app turns an Android phone or tablet into a data capturing device, with the possibility of importing .CSV files (field map, traits), exporting them via online sharing channels (cloud, email, instant messaging) or integrating them into a database using the BrAPI protocol. Field Book can also be operated completely offline. Data is always saved on the device's internal memory and can be manually transferred to a computer simply through a USB cable.

[17] it is essential that the EU data protection regulation (GDPR) is complied with, and that good practices such as informed consent are used. https://gdpr.eu/
[18] https://plantmethods.biomedcentral.com/articles/10.1186/s13007-020-00640-2
[19] https://cds.climate.copernicus.eu/#!/home and https://www.worldclim.org/
[20] https://esdac.jrc.ec.europa.eu/resource-type/european-soil-database-soil-properties

Conclusions and recommendations

Increased testing efforts for organic cultivar evaluation have an outstanding potential in enabling the success of organic farming and supporting the agroecological transition. However, current infrastructures are not fit for purpose in most European countries[21] and new models need to be designed to address the needs of a rapidly growing organic sector.

This booklet summarises the results of a collaborative effort among LIVESEED partners and stakeholders of several European countries, to address these needs and co-design the pillars of "**new models of cultivar testing for organic agriculture**" based on the analysis of objectives and constraints[22].

Some key elements emerge from this analysis and modelling work.

- On-farm decentralised cultivar trials require a **well established and functioning network**. Innovative cultivar trial models, free from the constraints of classical experimental designs (fully replicated RCBD/ANOVA), require networks from a minimum of 20 farms to well over 100, which represents an ambitious target in many European regions.
- Thriving cultivar trial networks require **skilled facilitators**, capable of motivating and engaging network members and drawing from participatory techniques to make the most of farmers' and stakeholders' knowledge of their environment and specific value-chain needs.

From an experimental design and data analysis perspective, the volume of information needed for meaningful organic cultivar testing is often higher and more nuanced than in a conventional setting. Yet, the organic sector is still too small to support the consequent additional costs, calling for innovative approaches to respond to the challenge. **Alternative experimental designs** and **collaborative digital platforms exist** (such as SeedLinked and Climmob, presented in this publication), which offer some insight into what a future **European model of organic cultivar testing may look like.**

The concept of "frugality" is key to develop a relevant, cost-effective and financially sustainable infrastructure through mobilisation, redirection and optimisation of available resources. However, to meet the ambitious target of 25% agricultural land under organic management by 2030 (as called for in Europe's **Farm to Fork Strategy**), the issue of economic sustainability for **Organic Plant Breeding** and **Organic Cultivar Trials** will need to be addressed at systemic level.
The methodology and examples presented in this booklet indicate that decentralised organic on-farm cultivar trial networks offer a cost effective solution to this problem and could play a pivotal role in boosting the organic sector, with targeted investments from both the public and private sectors.

[21] https://www.liveseed.eu/wp-content/uploads/2020/11/LIVESEED-D2.1_Overview-of-the-organisational-models-of-cultivar-trials-for-organic-agriculture_corrected-version_TMP.pdf
[22] https://www.liveseed.eu/wp-content/uploads/2021/02/21-01-29-LIVESEED_D2_3_final-compressed.pdf

Resources

FRUGAL INNOVATION

Radjou, N., Prabhu, J. C., 2015. Frugal innovation: how to do more with less. London: Profile Books Ltd.

Weyrauch, T., & Herstatt, C., 2017). What is frugal innovation? Three defining criteria. Journal of Frugal Innovation, 2(1), 1–17

MULTI-ACTOR NETWORK

Rey, F., Chable, V. (Eds.), 2018. Innovative approaches to embed diversity in food systems: DIVERSFOOD outcomes from field to plate. [online] Available from https://orgprints.org/id/eprint/35235/ (last accessed 24/04/21)

Rossi, A., Serpolay-Besson, E., Nuijten, E., Chable, V., 2019. Proven concept for a holistic, multi-actor approach suited for participatory research. Deliverable 1.3 DIVERSIFOOD. [online] Available from: http://www.diversifood.eu/wp-content/uploads/2019/03/DIVERSIFOOD-D1.3_Proven-concept-for-a-holistic-multi-actor-approach.pdf (last accessed 24/04/21)

Serpolay, E., Nuijten, E., Rossi, A. and Chable, V., 2018. Toolkit to foster multi-actor research on agrobiodiversity. Report. Diversifood. [online] Available from: https://orgprints.org/38153/ (last accessed 24/04/21)

Verrière,. P, Nuijten, E., Messmer, M.M., 2019. Organic plant breeding in a systems-based approach and integration of organic plant breeding in value chain partnerships. LIVESEED Milestone 3.5. [online] Available from https://orgprints.org/id/eprint/37972/ (last accessed 24/04/21)

PARTICIPATORY PLANT BREEDING

Almekinders, C.J.M., Mertens, L., van Loon, J.P. and Lammerts van Bueren, E.T., 2016. Potato breeding in the Netherlands: a successful participatory model with collaboration between farmers and commercial breeders. Farming Matters, April 2016, 34-37 (Special Issue).
https://orgprints.org/id/eprint/36940/

Annicchiarico, P., Russi, L., Romani, M., Pecetti, L., Nazzicari, N., 2019. Farmer-participatory vs. conventional market-oriented breeding of inbred crops using phenotypic and genome-enabled approaches: a pea case study. Field Crops Res. 232, 30-39.

Bhargava, A., Srivastava, S., 2019. Participatory plant breeding: concept and applications. Springer Singapore.

Ceccarelli, S., 2012. Plant Breeding with Farmers: A technical manual. Beirut, Lebanon: International Center for Agricultural Research in the Dry Areas (ICARDA). http://www.fao.org/family-farming/detail/en/c/326138/

Ceccarelli, S., 2015. Efficiency of plant breeding. Crop Science 55, 87–97.

Ceccarelli, S., Grando, S., 2020. Participatory plant breeding: Who did it, who does it and where? Experimental Agriculture, 56(1), 1-11.

Goldringer, I., Rivière, P., 2018. Methods and Tools for decentralized on farm breeding. Booklet #3. Diversifood Project. Available from https://orgprints.org/id/eprint/38157/ (last accessed 24/04/21)

Murphy, K., Lammer, D., Lyon, S., Carter, B., Jones, S.S., 2005. Breeding for organic and low-input farming systems: an evolutionary–participatory breeding method for inbred cereal grains. Renewable Agriculture and Food Systems 20, 48-55.

Nuijten, E.H., Janmaat, L., Lammerts van Bueren, E.T., 2013. New models for plant breeding: Key elements for collaboration within the food chain. Louis Bolk Institute Available from https://orgprints.org/id/eprint/27287/ (last accessed 24/04/21)

CROWDSOURCING, CITIZEN SCIENCE AND PLANT BREEDING

Van Etten, J., Beza, E., Calderer, L., Van Duijvendijk, K., Fadda, C., Fantahun, B., ... & Zimmerer, K. S., 2019. First experiences with a novel farmer citizen science approach: Crowdsourcing participatory variety selection through on-farm triadic comparisons of technologies (tricot). Experimental Agriculture, 55(S1), 275-296.

van Etten, J., de Sousa, K., Aguilar, A., Barrios, M., Coto, A., Dell'Acqua, M., ... & Steinke, J., 2019. Crop variety management for climate adaptation supported by citizen science. Proceedings of the National Academy of Sciences, 116(10), 4194-4199.

Van De Gevel, J., van Etten, J., & Deterding, S., 2020. Citizen science breathes new life into participatory agricultural research. A review. Agronomy for Sustainable Development, 40(5), 1-17.

ECONOMIC MODELS

Kotschi, J., Doobe, L., Schrimpf, B., Waters-Bayer, A., 2021. Enabling diversity: ways to finance organic plant breeding. Discussion Paper. AGRECOL Association, Guggenhausen. Available from https://opensourceseeds.org/sites/default/files/bilder/Enabling%20diversity_Agrecol_21-01-2021.pdf (last accessed 15/04/2021)

Kotschi J and Wirz J, 2015. Who pays for seeds? Working paper. AGRECOL and Section for Agriculture Goetheanum. Available from: https://www.opensourceseeds.org/sites/default/files/downloads/Who_pays_for_seeds.pdf (last accessed 10/09/2020)

Kovács, T., Pedersen, T. M., 2019. Overview on the current organizational models for cultivar testing for Organic Agriculture over some EU countries. [online] Available from: https://orgprints.org/id/eprint/37818/ (last accessed 24/04/21)

Nuijten, E., de Wit, J., Janmaat, L., Schmitt, A., Tamm, L., Lammerts van Bueren, E.T., 2018. Understanding obstacles and opportunities for successful market introduction of crop varieties with resistance against major diseases. Organic Agriculture 8 (4), 285-299.

Lazzaro, M., de Porras Acuna, M. A., Schäfer, F., Neff, A. S., & Messmer, M., 2020. Securing organic animal and plant breeding through a common cross-sector financing strategy. Organic Animal Husbandry systems-challenges, performance and potentials, FiBL, 99-100. Available from https://orgprints.org/id/eprint/38820/ (last accessed 25/04/21)

Weibel, F. P. (2001). Organic fruit production in Switzerland: research and development to resolve cultural, management, and marketing problems. American Journal of Alternative Agriculture, 16(4), 191–195.

Wirz., J., Kunz, P., Hurter, U., 2017. Seed as a Commons: Breeding as a Source for Real Economy, Law and Culture: Assessment and Future Perspectives for Non-profit Seed and Breeding Initiatives. Goetheanum.
Available from https://www.sektion-landwirtschaft.org/fileadmin/SLW/Literatur/Saatgutstudie/seeds_as_a_commons.pdf (last accessed 21/04/21)

EXPERIMENTAL DESIGN AND DATA MANAGEMENT

BERTI-EQUILLE, L., 2004. Qualité des données. Ingénierie des Systèmes d'Information.. Vol.9, 117–143.

Brown, D., Van den Bergh, I., de Bruin, S., Machida, L., & van Etten, J., 2020. Data synthesis for crop variety evaluation. A review. Agronomy for sustainable development, 40(4), 1-20.

Colley, M., Dawson, J., Zystro, J., Healy, K., Myers, J., Behar H, and Becker, K., 2018. The Grower's Guide to Conducting On-farm Variety Trials. Organic Seed Alliance [online] Available from: https://seedalliance.org/wp-content/uploads/2018/03/Growers-guide-on-farm-variety-trials_FINAL_Digital.pdf (last accessed 25/04/21)

De Oliveira, Y., Burlot, L., Dawson, J. C., Goldringer, I., Madi, D., Rivière, P., ... & Thomas, M. (2020). SHiNeMaS: a web tool dedicated to seed lots history, phenotyping and cultural practices. Plant Methods, 16(1), 1-9. Available from: https://plantmethods.biomedcentral.com/articles/10.1186/s13007-020-00640-2

Donner, D., Osman, A. (Ed.), 2006. Handbook: Cereal variety Testing in Organic and Low Input Agriculture. Ed., COST860 –SUSVAR [online]
Available from: https://library.wur.nl/WebQuery/edepot/116544 (last accessed 25/04/21)

Gauch Jr, H. G., Piepho, H. P., & Annicchiarico, P. (2008). Statistical analysis of yield trials by AMMI and GGE: Further considerations. Crop science, 48(3), 866-889.

Goldringer, I., Rivière, P., 2018. Methods and Tools for decentralized on farm breeding. Booklet #3. Diversifood Project. Available from https://orgprints.org/id/eprint/38157/ (last accessed 24/04/21)

Rivière, P., Dawson, J. C., Goldringer, I., & David, O. (2015). Hierarchical Bayesian modeling for flexible experiments in decentralized participatory plant breeding. Crop Science, 55(3), 1053-1067.
Available from: https://doi.org/10.2135/cropsci2014.07.0497 (last accessed 25/04/21)

Rife, T. W., & Poland, J. A. (2014). Field book: an open-source application for field data collection on android. Crop Science, 54(4), 1624-1627.

Rivière, P., Franck, G. van, David, O., Munoz, F., Rouger, B., Vindas, C., Thomas, M., Goldringer, I., . An R package to perform analysis found within PPB programmes. [online]. Available from: https://priviere.github.io/PPBstats_web_site/ (last accessed 25/04/21)

Rodríguez-Álvarez, M. X., Boer, M. P., van Eeuwijk, F. A., & Eilers, P. H. (2016). Spatial models for field trials. arXiv preprint. Available from: https://arxiv.org/abs/1607.08255 (last accessed 25/04/21)

Vindras, C., Sinoir, N., Coulombel, A., Taupier-Letage, B., Rey, F.. 2018. Tasting guide: Tools to integrate organoleptic quality criteria into breeding programs. Technical booklet. Diversifood Project. [online] Available from: https://orgprints.org/id/eprint/38095/ (last accessed 25/04/21)

Zystro, J., Colley, M., & Dawson, J. (2018). Alternative experimental designs for plant breeding. Plant Breeding Reviews, 42, 87-117.

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LIVESEED

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BOOSTING ORGANIC SEED AND PLANT BREEDING ACROSS EUROPE

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