Frugal, multi-actor and decentralised cultivar evaluation models for organic agriculture:
methods, tools and guidelines

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Authors	Frederic Rey, Pierre Rivière, Emma Flipon (ITAB), Abco de Buck (LBI), Judit Feher (ÖMKi), Ambrogio Costanzo (ORC), Mariateresa Lazzaro (FiBL-CH)

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Executive Summary

The new Organic Regulation EU 848/2018 recognises the priority of developing cultivars[1] suitable to organic agriculture. Such cultivars must have i) an ability to cope with natural biotic and abiotic stressors; ii) a capacity to adapt to "*diversified local soil and climate conditions and to the specific cultivation practices of organic agriculture" and iii)* a capacity to produce high-quality food to meet the expectations of organic consumers. In fact, when the use of external inputs (mineral fertilisers, herbicides and pesticides) that can mitigate environmental stressors and buffer environmental variation is excluded or limited, cultivar choice is the key crop-specific decision organic farmers can make.

Suitable cultivars for organic agriculture can be sourced via three channels (Wolfe et al. 2008): i) cultivars issued from conventional breeding; ii) cultivars bred for traits relevant to organic agriculture; iii) organic cultivars for which the entire breeding process is conducted under organic conditions and following organic principles. Whichever of the above channels is considered, cultivar adaptation to farming systems, the environment and the market in which farmers operate can only be ensured by an optimal information flow about cultivars' performance under organic conditions. Such flow of information can be enabled, in turn, by appropriate cultivar evaluation. In conventional agriculture, post-registration cultivar evaluation is mainly performed on controlled experimental sites and its results are used by extension services to provide variety recommendations for farmers. This system requires a great investment in terms of logistics and infrastructure, and is extremely labour- and cost-intensive, while providing information of limited relevance to organic farmers. In fact, performance ranking of cultivars can change considerably whether the evaluation is done in conventional or in organic conditions. Moreover, organic food and farming systems are highly diversified, with many different crops being cultivated in diverse contexts and for different purposes, and are exposed to higher environmental variability than in conventional systems.

Since organic agriculture only represents a fraction of the whole agricultural sector, few cultivar evaluation programmes dedicated to organic agriculture exist in Europe; most of these follow the same architecture used in conventional systems, and are limited to few major crops. Therefore, they are far from responding to the complex information needs required by the highly diverse organic systems. To overcome this lock-in, radical innovation pathways are needed, to explore innovative models for cultivar evaluation under Organic Agriculture.

In the framework of LIVESEED, several partners joined forces to co-design effective and innovative cultivar evaluation models, also keeping in mind their applicability in European countries with limited or no infrastructure, the potential and challenges of conducting on-farm and participatory trials, the issues of data quality and cost-efficiency. These models should encompass both social and technical dimensions and include the concepts of on-farm decentralized evaluation, participative and multi-actor networks and frugal innovation. This is the scope of this report under the project Deliverable 2.3.

[1] 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 Heterogenous Material (cf. the new Organic Regulation 2018/848/EU).

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To **design these new models**, the "Define – Knowledge – Concept – Project" (DKCP) process based on the Concept-Knowledge (C-K) theory, was implemented in four steps: Definition of the area to be explored, Knowledge sharing, Concepts design and Project development. Following this process, several workshops and webinars brought together researchers from institutes across various European countries. These activities led to propose appropriate solutions to overcome the current lock-ins and meet the objective of "setting up and/or optimising cultivar testing networks for organic farming". The key concept guiding and supporting the development of tailor-made solutions is that of **"frugal innovation"**, based on which a strategy based on an evaluation of objectives and constraints was developed, inspiring examples were shared and crop specific protocols proposed.

In this proposed strategy, **participatory approaches** are not only ethically preferable, but essential to cover the wide range of needs and environmental conditions of organic farming, as well as to mobilise resources in a frugal framework. **Coordination and facilitation** of a collaborative network are fundamental and require appropriate skills and methods to act as innovation brokers and "catalysers" of empowerment**.**

For many constraints, there are **statistical methods** that can generate robust and useful decision-making data. Several scientifically validated experimental designs were proposed based on the types of data and specific constraints, for instance the number of cultivars to be tested, the number of farms involved and if replications are needed.

Economic models need to be chosen through exploring or combining different approaches, from public support, to subscription-based or supply-chain cost recovery models. The final model should be developed around and integrated into broader breeding programme financing strategies. In this respect, alternatives to the royalty-based breeding business models can be developed for organic cultivar testing, given their inappropriateness to the need to significantly diversify the pool of varieties for organic farming.

Finally, the concepts of a future solution have been drawn, proposing a new European model of cultivar testing based on a collaborative digital platform. **Integration of ICT technologies** can be a lever to facilitate frugal, highly inclusive and representative cultivar trialling infrastructures, as proven by existing initiatives (Brown et al., 2020, Van Etten et al., 2019) that will need to be further explored and potentially adapted to the European context.

Developing an effective cultivar testing infrastructure can reinforce the role of organic farming in being pivotal for a broader transition towards agroecological food and farming systems. Organic cultivar testing models must therefore be seen as a highly strategic objective the societal impact of which can, in the long run, be critical for the whole European agricultural sector.

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This report is the fruit of a successful collective work, that involved several LIVESEED researchers from institutes across various European countries.

The design of the innovative models presented in this report was a one-year process monitored by a steering committee coordinated by Frederic Rey (ITAB), supported by IDEAS (Laura Le Du, Arnaud Gauffreteau, Mariane Cerf) for the methodological and back-office activities, and composed of Abco de Buck (LBI), Judit Feher (ÖMKi), Tove Pedersen (SEGES), Ambrogio Costanzo (ORC), Matteo Petitti (RSR), Agnes Bruszik (IFOAM-OE), Monika Messmer and Mariateresa Lazzaro (FiBL CH), and Emma Flipon (ITAB).

These steering committee members were involved in Workshops and Webinar discussions, together with other partners: Enguerrand Burel (ITAB), Szilvia Bencze (ÖMKi), Kostas Koutis (Aegilops), Roberto Ruiz de Arcaute Rivero (SEAE), Peter Miko (MTA), Gebhard Rosmanith and Janine Zibi (Bingenheimer Saatgut), Mathias Klaiss (FiBL-CH), and Charlotte Bickler (ORC).

Based on these workshops, on the analysis of previous studies and running projects, and on case studies with comparative field trials, this report was written by:

- chapter 1: Abco de Buck (LBI), Ambrogio Costanzo (ORC), Emma Flipon and Frederic Rey (ITAB)
- Chapter 2: Laura Le Du (Ideas/ITAB), Emma Flipon and Frederic Rey (ITAB)
- Chapter 3&4: Pierre Rivière (Mètis/ITAB), Frederic Rey (ITAB), Mariateresa Lazzaro (FiBL-CH - chapter 3.5)
- Chapter 5: Judit Feher (ÖMKi) and crop experts
- Chapter 6: Frederic Rey (ITAB), Ambrogio Costanzo (ORC)

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1 Introduction

Organic crop production shows a gap in yield compared to conventional agriculture (Knapp and van der Heijden, 2018). At least part of this gap can be attributed to the limited or suboptimal availability of cultivars adapted to organic farming. Indeed, with limited use of external inputs, organic agriculture relies on the ability of the crop to interact with natural resources and processes, such as the ability to compete with weeds, to tolerate or resist to pests and diseases and to efficiently mineralise soil organic matter. These processes do not follow fixed patterns, but are influenced by the variations and interactions that occur in the abiotic and biotic environment.

There is a growing consensus about the fact that organic farming would greatly benefit from cultivars that are bred and tested in the complex target environment of organic systems (Murphy et al., 2007), hence becoming fully adapted to these. Wolfe et al. (2008) summarised the three main breeding and variety testing models on which organic agriculture currently can rely on:

- 'conventional breeding', *i.e.* reliance on varieties bred for conventional agriculture, which still represents the vast majority of the organic seed market;
- 'breeding for organic', *i.e.* breeding varieties in line with organically-relevant trait architectures, and/or late stages of varietal selection held in organic conditions, which is a currently growing market;
- 'organic breeding'[1] *i.e.* direct selection and/or most of the breeding programme held in organic conditions and following organic principles.

'Organic breeding' is currently a niche, but it could represent the ultimate step of a transition from the currently limited and fragmented use of organic seed (Orsini *et al*., 2020) towards a situation where seed is not just an 'input' but an integral part of the agroecosystem. This shift would also respond to the provisions of the new EU Organic Regulation 848/2018, which introduces the concept of 'plant reproductive material adapted to organic agriculture' and, especially, the concepts of 'organic varieties' and 'organic heterogeneous material'.

Indeed, the three concepts summarised by Wolfe et al. (2008) could be interpreted as corresponding with the three stages of 'efficiency', 'substitution' and 'systems redesign' of the agroecological transition as described by Hill and MacRae (1996). Conducting variety trials under organic conditions is key to addressing all the three steps of the transition (Costanzo *et al*.;. *in prep.*). As such, it is the object of increased attention at the European level, although it is addressed via various approaches across regions, with differing levels of public and private support.

Given the complexity of ecological interactions underlying organic production, an efficient cultivar testing infrastructure is key to unlock the information flow which enables the allocation of "the right cultivar to the right farm". Indeed, the extent to which organic seed, generated by either 'conventional' breeding, 'breeding for organic' or 'organic breeding', can ensure optimal performance is largely dependent on the efficiency of the cultivar testing infrastructure (Fig. 1).

[1] The LIVESEED project follows the definition of organic plant breeding provided in the International IFOAM Norms on Organic Production and Processing (Version 2014).

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In this introductory chapter, we explore (1.1) the specific phenotypic needs of organic farming, the currently existing official (1.2) and non-official (1.3) data sources on cultivars, highlighting the main information and organisational gaps, and finally we identify (1.4) the key assumptions and concepts to shape efficient cultivar testing infrastructures for organic agriculture.

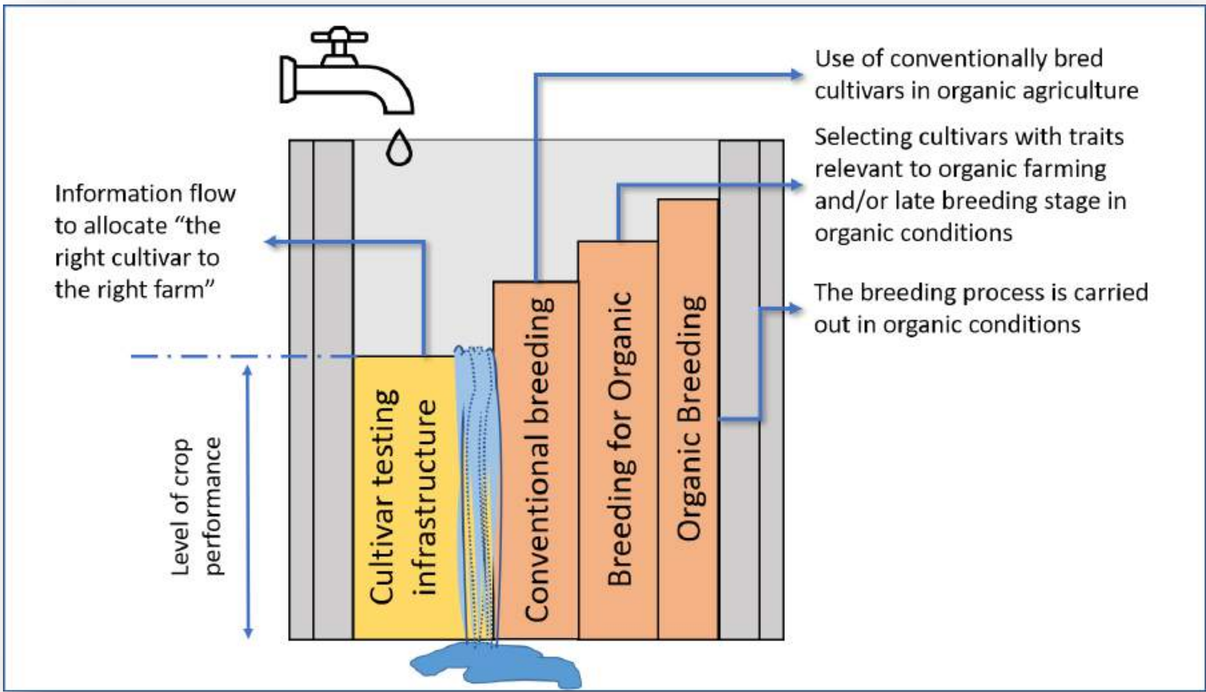

Figure 1. *The importance of an appropriate cultivar testing infrastructure to raise the performance of organic farming, described metaphorically as inspired by the 'Liebig Barrel' law of the minimum. The use of cultivars bred and tested though the conventional system, or through breeding for organic agriculture or organic breeding (Wolfe et al. 2008) are interpreted as stages of a transition towards a more efficient organic breeding and seed system. However, the three above breeding models can only fulfil their progressively higher potential of raising crop performance as long as an appropriate cultivar testing infrastructure is in place under organic conditions, to enable an optimal information flow.*

1.1 The need for appropriate cultivars for organic agriculture

Organic crop production shows a gap in yield and is less stable over seasons compared to conventional agriculture (Knapp and van der Heijden, 2018). At least a part of this gap can be attributed to the scarce availability of cultivars specifically adapted to organic agriculture, meaning that farmers have no other choice than use cultivars developed and tested for conventional systems, which are thus not the best option for organic farming. Furthermore, cultivars that are resilient to low-input conditions and environmental variability are likely to become more relevant for conventional farming as well, in light of climate change and the increasing limitations on the use of pesticides.

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Due to substantial R&D efforts over the last decades, conventional variety development allowed to significantly improve the genetic yield potential of the newly released varieties in a number of crop species (*e.g.* Rijk *et al*., 2013). For organic breeding programmes and organic cultivar testing, however, it has been difficult to find the resources necessary for investing in a range of crops. The small number of cultivars truly adapted to organic farming is recognized as a main bottleneck for the development of the organic farming sector as a whole (LIVESEED D2.4; Pedersen *et al. in prep.*). The main problem is the small market potential for organic seed (market pull). Despite decades of constant growth in the demand for organic food, organically farmed land still represents only 2,9% of the total farm land in Europe (Willer *et al*., 2019).

Organic agriculture differs from conventional agriculture in terms of how it uses diversity at different levels. Organic farming requires the use of crop rotations, based on a wide range of crops and promotes the use of locally adapted cultivars. Organic crop rotations also include minor and neglected species, each covering an often relatively small area. This means that the area under production of a single cultivar can be small, despite the overall importance of the crop species the cultivar belongs to and the share of organic farmland the crops covers (LIVESEED D3.5). Hence, organic farming needs an even broader cultivar base than conventional farming, as these should be locally adapted to each specific and more variable growing conditions and to local market preferences. A better suited seed assortment for organic farming could increase farms' productivity, yield stability, the quality of end products, the farm income and benefit the whole organic value chain.

The urgency of an appropriate cultivar portfolio differs between crop species in the different plant production sectors (*e.g.* arable farming, vegetable and fruit growing). Some specific reported bottlenecks are:

- The lack of breeding efforts and testing capacities for organic wheat cultivars can be attributed to the small market potential and small financial benefits through the value chain (Costanzo *et al. in prep*.)
- Market potential is low for small crops (*e.g.* dry beans and all kinds of heritage vegetables) and crops for niche markets (*e.g.* specialized organic retailers or local food markets).
- Cultivar improvement through biotechnological innovations is gaining ground, resulting in hybrids or line varieties that are not always fitted for organic farming (*e.g.* tomato and wheat) or not accepted by some organic stakeholders (*e.g.* C.M.S. -Cytoplasmatic Male Sterility- in Brassica varieties).
- The introduction of new fruit tree cultivars takes a very long time and a strong commitment and effort from all stakeholders in the value chain. Specific cultivar development for the organic market imposes additional risks, even if some relevant varieties for organic agriculture have great potential for the conventional sector as well (*e.g.* scab resistant apple cultivars).

As insufficient organic seed is available for many crops, farmers are allowed to request derogations to use conventional seed (untreated after harvest) instead. However, in line with the new EU organic regulation (2018/848/EU), these derogations will be phased out by the end of 2035. On the other hand, the European Commission states the ambition in the recent Green Deal Farm to Fork strategy to achieve 25% of agricultural production as organic. This is an additional reason why farmers should have a significantly wider choice of organic varieties (bred according to organic principles and evaluated under organic conditions) and conventionally bred varieties, tested under and suited to organic production systems. Gathering information on the performance those cultivars under organic conditions is an important part of the effort.

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1.2 How does a variety access the seed market: registration trials

To be marketed, a variety must be registered in the official variety catalogues, which requires testing its compliance with the Distinctness, Uniformity and Stability (DUS) criteria. For field crop, additional tests on the Value for Cultivation and Use for the market (VCU tests) are also required. DUS and VCU are evaluated in trials which follow specific protocols, and are carried out by the national registration bodies. When any new variety passes the trialling procedures, it is registered in the official National Variety List and the EU 'Common catalogue of varieties of agricultural plant species'. This listing is the precondition for the commercial sale of seed of any variety and for the entitlement of any Intellectual Property Rights (IPR).

DUS tests aim at ensuring that new varieties can be clearly and unequivocally identified. DUS testing protocols are based on the assessment of characteristics for which there is a great degree of phenotypic variation between varieties. These traits do not necessarily have value for the user (*e.g.* botanical characteristics like leaf shape and length). Whilst the DUS trials mostly aim at identification and therefore have little relevance to predict cultivar performance, VCU trials can potentially offer valuable information on relevant agronomic or other performance characteristics, allowing a better informed cultivar choice. The VCU tests are mainly aimed at ensuring that new varieties offer some form of added value compared to existing reference varieties on the market. The results are published in the national recommended list of varieties. The testing procedure, however is largely focused on yield and few other relevant traits for mainstream production systems (for example quality for industrial processing) and is mostly carried out under conventional conditions.

Kovács and Pedersen (2019) evaluated and compared the current variety trials (including DUS and VCU testing) across 15 EU countries. VCU testing varies widely by country. Most EU members that have official VCU variety testing systems, do not have specific VCU testing infrastructures under organic conditions for varieties which have potential for use in organic agriculture (obtained through organic or conventional breeding approaches). The greatest challenge is to keep the costs of the VCU testing infrastructure acceptable for the breeder. Sometimes, financial support is provided by governments.

The undesirable situation of inappropriate testing procedures for the registration of cultivars that have potential for organic farming was already tackled by previous EU projects (*i.e*. DIVERSIFOOD, COBRA and COST Action project SUSVAR) which highlighted the problem of farmers and buyers not having adequate information for choosing the cultivar that best fits their situation. The conventional testing infrastructure, albeit cost-effective considering the large turnover in the seed sector and the R&D efforts spent for the development of high yielding cultivars, is expensive (mainly due to high labour intensity). As the organic sector is still small and so is the market potential of organic seed, a specific testing infrastructure for organic farming will hardly benefit from the economies of scale as it does in the conventional seed sector.

Before a cultivar is registered and released to the market, (pre-registration) genotype testing has been done in the selection phase by the breeder. Breeders that are fully dedicated to organic farming will conduct the whole breeding and selection processes under organic conditions. While not part of formal cultivar testing and not independent, breeders' selection trials give a first indication of the properties of a new cultivar. Well designed non-official cultivar testing networks (of *e.g.* farmers,

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breeders and buyers) for organic farming could be very useful to speed up variety development and reduce costs, with benefits across the whole organic sector.

1.3 Non-official evaluation trials

Organic farming differs substantially from conventional systems, where variability is buffered and controlled by external inputs (Fig. 2). As a consequence, cultivars' performance will rank differently under organic conditions compared to conventional, and will vary across organic sites more widely than across non-organic sites. In order to make a good cultivar choice, a farmer needs information that applies to her/his specific context. Information on the value or performance of (new) cultivars can be retrieved from comparative trials under organic management.

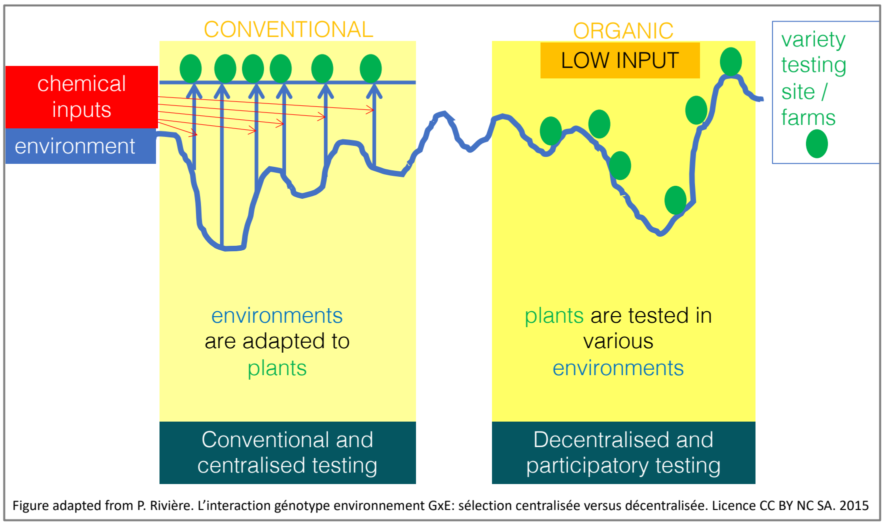

Figure 2 *- In conventional farming, the environments are adapted to the plants by the buffering effect of chemical inputs. In organic farming, the plants need to adapt to the environment (Genotype x Environment interactions). This asks for decentralised and participatory variety testing on multiple farm sites.*

The performance of agricultural production systems is mainly assessed by observations conducted at a centralized, experimental plot scale. Yield gaps between plot-scale and field-scale experiments are widely recognized, but less investigated; *e.g.* by Kravchenko *et al.* (2017) and Rijk *et al.* (2013). Rijk *et. al* (2013) report that the yield gap between controlled variety trials and on-farm sites under conventional management has tended to increase over the last decade. This growing gap between varieties' potential and actual yield could indicate that conventional farming already relies too much on potentially high yielding cultivars which however have insufficient buffering capacities to attain this high production level even in conventionally managed fields. According to Fig. 2, Kravchenko et al. (2017) show that in organic and low-input systems, results from plot-scale trials are even less consistent with field-scale performance compared to conventional farming.

Next to the official pre-registration trials, Kovács and Pedersen (2019) also evaluated post-registration trail systems for organic cultivars across 15 EU countries for arable and forage crops, vegetable and fruit crops. Four main aspects are evaluated: the trial setup, the organizational model, the dissemination of results and the financial model. Post-registration testing shows a large variation by

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country and by crop type; most facilities are available for the major arable crops with a substantial market share, while –due to the fragmented market- hardly any independent cultivar trials are done for organic vegetables. Many countries have no system of independent cultivar testing under organic conditions. Independent, un-official on-station testing is done by research institutions and universities, funded by governments or private companies. Non-official, independent variety trials are also sometimes carried out on-farm. Testing under on-farm conditions in different pedo-climatic regions gives a variety performance that is more realistic for the user (Lyon et. al. 2019).

A range of organizational models for variety trials is described in D2.1 (Kovács and Pedersen, 2019). Some of them are mainly governmentally supported and involve researchers. Most breeding companies have their own variety trials, which is a good way to showcase of their own material, but not an independent cultivar trial for what's on the market. However, Kovács and Pedersen also found examples where breeders and seed companies were engaged in independent trials. In some cases, variety trials are established by farmers and run on a voluntary basis. Organizational models tend to be rather complex. Funding is mostly a combination of government supported institutions, levies, membership fees, and temporary project funding. Hence, institutes or initiatives organize trials depending on the available socio-economic conditions, such as funding sources, economic importance of the crop in the country, chain actors' engagements, organic sector development, existing trial infrastructure, etc.

Figure 3 summarizes a complete testing cycle of official registration and non-official post-registration trials for conventional varieties. The results are disseminated as variety recommendations for the farmer. This is mostly organized by researchers who are usually also the trial coordinators or in some cases it is taken over by an advisory or education service. Institutes mainly publish results on a yearly basis, usually making them publicly available, but sometimes just within the network. In case the institute is authorized to perform VCU trials, the results are included in the official national recommended list of varieties for organic farmers.

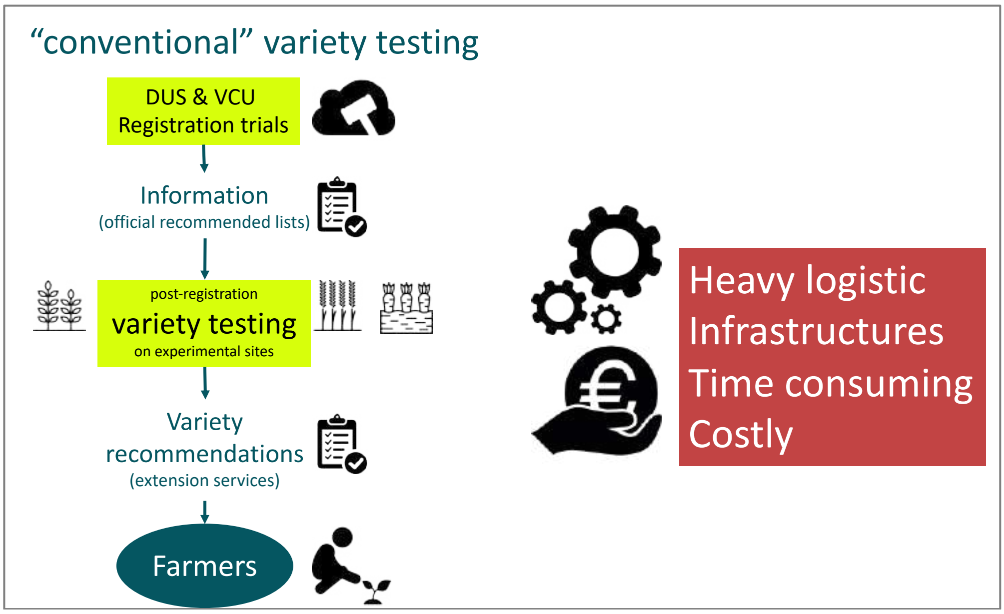

Figure 3 *- As "traditional" testing is expensive and financial resources lacking, only few cultivar trialing networks exist in Europe, not in every country and only for a few major crops.*

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Like official testing, informal post-registration cultivar testing is labour intensive and expensive, especially when conducted on-station. Furtner, as explained, the diversified nature of organic food and farming systems requires more decentralized testing of cultivars for organic agriculture. Therefore, in order to provide accurate information on cultivar performance to organic farmers, cost-effective alternatives need to be devised.

For most crops, the lack of testing of the users' value of plant varieties under real-life organic farm conditions is recognized as a major bottleneck for the development and dissemination of organic varieties in almost every country (Kovács and Pedersen, 2019). All food chain partners have their specific value requirements; especially in the more specialized and localised organic markets. Thus, the relevance involving them in evaluating varieties in systematic and independent trials is obvious, leading to the importance of designing more participative and multi-actor cultivar testing networks for the organic sector (Fig. 4).

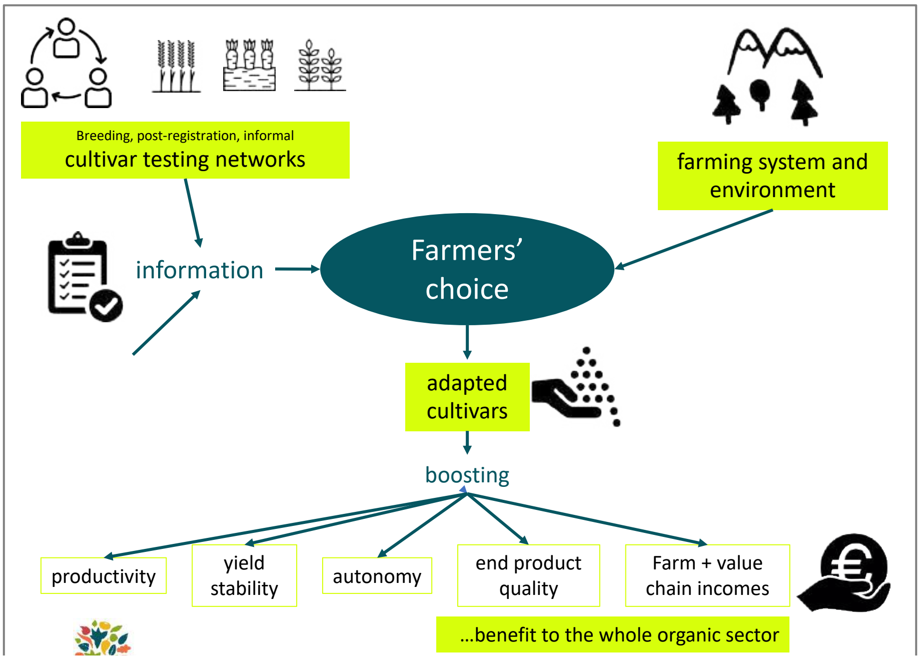

Figure 4*- Well organised cultivar testing networks can deliver valuable information to farmers and in the end boost the farm performance and income*

Concluding, the information currently available to organic farmers on the value of (new) cultivars is highly incomplete. The main reasons are:

- Trials are mainly carried out under conventional conditions, where cultivars perform differently than under organic management, leading to information which is of scarce relevance to organic farmers.
- Cultivar performance is derived from experimental, plot-scale trials that differ significantly from what happens in field scale conditions.
- Only species with a substantial market potential (in terms of volume or profitability) are tested.
- As cultivar testing is expensive and financial resources scarce, only few cultivar testing networks exist in Europe, not in every country and only for a few major crops.
- When cultivar trials are organised on-farm, they often require heavy logistics, data return is slow and low, results are shared too late, and in the end trials will have limited efficiency and impact.

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1.4 Concepts for efficient cultivar testing infrastructures

For reasons mentioned in previous sections, new models for variety testing for organic agriculture are needed. Meanwhile, it is unrealistic and probably undesirable to develop a similar model as the one used in the conventional trialing (Fig. 3). Unrealistic, as the resources involved would make it far too expensive. Undesirable, given the large variety of growing conditions under organic farming and the already described issues of plot versus field scale trials, which are especially relevant to organic contexts. **In essence, the paradox is that organic cultivar testing needs greater efforts, while the funding available is scarce**. This calls for out-of-the-box solutions to design cost-efficient or low cost, decentralized and participatory on-farm testing systems for the organic sector, as described in this section.

All the stakeholders of organic value chains could together contribute to building cost-effective cultivar testing models with knowledge, seed material, in kind or financial support. Farmers' involvement holds great potential, as they have at hand all necessary resources to conduct a field trial. On-farm trials can be carried out with (newly) registered varieties, with new breeding lines that are not registered (yet) or other kinds of cultivars such as landraces. An on-farm trialing network can help breeders to receive early feed-back from farmers, speed up market release and encourage adoption by famers. In this model, farmers can also act as 'innovation brokers', sharing the best adapted cultivar among their peers. A low-cost system might be also a solution for so called "minor or underutilised" crops that are not grown on a large scale and have a small market share but potentially a high potential for farming system diversification.

Each sector has its own characteristics that requires a specific testing system. The vegetable sector for example is fragmented and adapted to local conditions and markets, which makes a local testing network involving value chain actors useful, as opposed to the more uniform and large scale arable crops sector. For perennial crops, there is a tradition of strong farmer and value chain actor involvement due to the long-term nature of cultivar development. This could facilitate the development of new testing models in this sector. Especially the fruit sector could benefit of organic testing networks, due to the typical long term life cycle of fruit trees and cultivar development.

The following sections describe the basic concepts of innovative models for cultivar testing in organic agriculture: decentralized evaluation, participatory and multi-actor evaluation networks and frugality.

1.4.1 Decentralised evaluation

Organic farming systems and practices are very diverse. It is challenging to represent such diversity in a system for cultivar evaluation. Decentralizing the trials by conducting them in different target environments is a solution to increase their efficiency, especially under organic conditions where GxE interactions are so important (Wolfe et al, 2008; Ceccarelli, 2015). Specific on-farm trial networks can be implemented to reach this objective (Goldringer and Rivière, 2018; van Etten et al, 2016).

1.4.2 Participatory and multi-actor evaluation networks

In order to integrate end-users' needs and objectives, the evaluation must be participatory and follow a multi-actor process. In a multi-actor network, the evaluation actively involves different actors (farmers, technicians, researchers, facilitators, consumers, etc.), each contributing their knowledge and experience in different ways (Serpolay and al, 2018). Such an approach allows sharing knowledge and skills about the trial methodology, the variables to be measured, approaches to field evaluation,

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etc. It also allows integrating the preferences and needs of each involved stakeholder in a holistic approach. In a multi-actor network, stakeholders share common objectives and, to achieve these, a strong commitment to work together. Participatory research can improve the efficiency, effectiveness, and scope of research processes, and foster social inclusion, empowerment, sustainability, and may better answer the real needs of the actors of the network (Sperling et al. 2001; Gevel (van de) et al, 2020): "the whole is greater than the sum of the parts".

1.4.3 Frugal innovation

When performed under the same model as conventional evaluation on station, decentralized evaluation in a multi-actor network requires a a great degree of labour and financial resources (cf. section 1.3). Indeed, mimicking station management across different farms within a network is basically impossible: the same material and technical support available in a research and experimental station cannot be provided in each farm. To overcome this problem, the frugal innovation concept can help (Box 1) in designing systems and solutions that respond to specific needs of the network (e.g. in terms of scale, financial and practical means, time), by embracing its constraints and using them as a tool to find innovative approaches.

Frugal innovation is an approach that helps create products and services which have a strong added value and are accessible to as many people as possible. It responds to very actual social, environmental, and economic needs while saving precious resources such as energy, capital and time.

BOX 1 - The 10 principles of frugal innovation (adapted from Radjou and Prabhu, 2015 and A. AGARWAL, www.frugal-company.com)

1. The solution is in the problem
2. Simplify what's complex- keep it simple
3. Think about a solution that is both sustainable and accessible
4. Attribute new functions/tasks to underutilized resources - do not reinvent the wheel
5. Use new technologies as a lever to democratize, decentralize and "disintermediate"
6. Foster co-creation along the whole value chain
7. Use constraints as a lever to make ingenuity arise
8. Give responsibility and autonomy to the smallest unit - think and act horizontally (scaling out)
9. Foster diversity
10. Contribute to the common good

In line with the second principle (Box 1), "simplify what is complex", the frugal innovation strategy invites to observe the problem by trying to unravel specific target objectives related to a situation. The constraints associated with those objectives must then be identified and considered as opportunities to develop original ideas. These ideas can be achieved by encouraging cooperation among actors related to the project, identifying the resources already available, and to finding a solution which is robust, modular, simple and sustainable. Finally, the economic viability of the project has to be thought through, in line with innovative value distribution models.

In short, this strategy can be summarised into three steps: 1) Set up the objectives; 2) Identify the constraints; 3) Propose solutions.

To develop new models of cultivar testing for organic farming, the LIVESEED project implemented this frugal innovation strategy. A series of workshops and webinars was organized, the method and outcomes of which are presented in Chapter 2.

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2 Methodology

To design innovative socio-technical organisation models of cultivar testing for the organic sector, we used the C-K theory (C for Concept ; K for Knowledge), which is particularly adapted to explore new concepts and their properties (Hatchuel & Weil, 2009). To collectively activate the design reasoning towards developing the C-K theory, we used the "Define – Knowledge – Concept – Project (DKCP)" (Le Masson et al., 2014) process based on the Concept-Knowledge (C-K) theory, implemented in four steps: Definition of the area of the exploration, Knowledge sharing, Concepts design and Projects development (Fig. 5).

In a first step, we collectively identified the values associated with cultivar trial networks for organic agriculture, in order to define the scope of the problem (Workshop #1 – Phase D). Then, some "projector concepts" were formulated to focus the exploration on complementary issues (Fig. 6). To feed the reasoning, knowledge was introduced (sharing session - Phase K ; Fig. 7): experts were identified related to each of the projector concepts. After a briefing, they exposed their experiences and answered the questions of the group. For the second workshop (Workshop #2 – Phase C), we decided to focus on the exploration of one projector project in particular (Fig. 8). Moreover, to facilitate the translation of participants' ideas into projects, the scenario method was used (Julien et al., 1975), which means that two methods were combined.

The full process was managed by a steering committee, which worked behind the scenes during the whole design process to organise, facilitate and capitalize on the products.
This steering committee group was coordinated by ITAB (Frederic Rey and Emma Flipon), supported by IDEAS (Laura Le Du and Arnaud Gauffreteau) for the methodological and back-office activities, and composed of the Task 2.1 leader (LBI, Abco de Buck), subtask leaders (ÖMKi, Judit Feher; SEGES, Tove Pedersen; ORC, Ambrogio Costanzo; RSR, Matteo Petitti; IFOAM-OE, Agnes Bruszik) and the project scientific coordinators (FiBL CH, Monika Messmer and Mariateresa Lazzaro).

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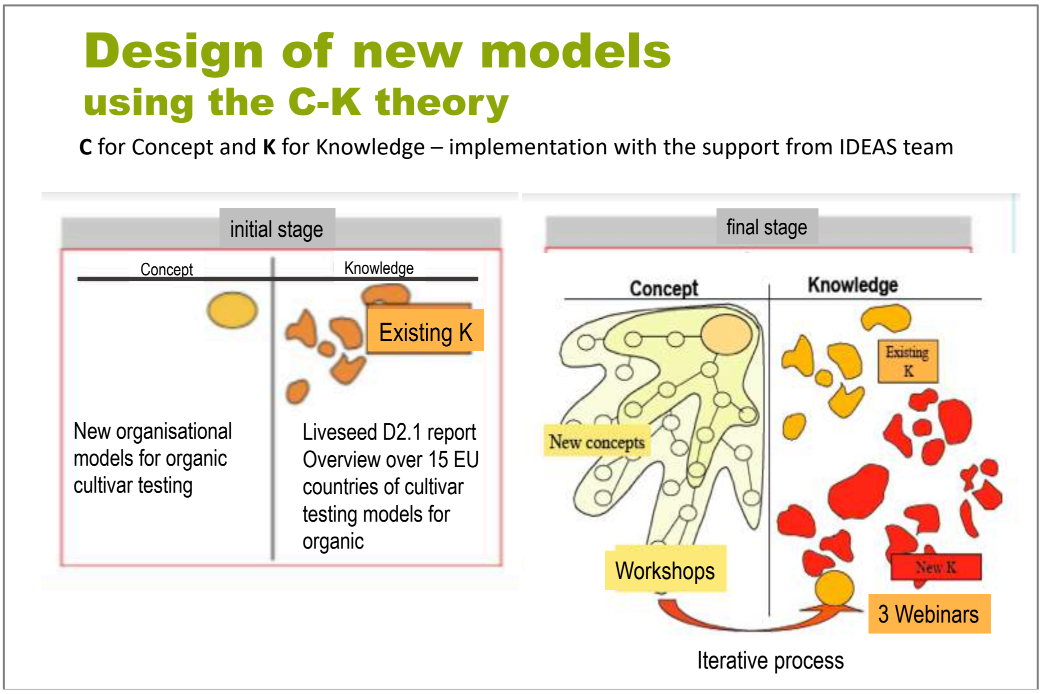

***Figure 5** – Illustration of the "Define – Knowledge – Concept – Project (DKCP)" method implemented. At the initial stage, there was one main concept "New models of cultivar testing for organic" and a report (D2.1), as main existing knowledge. Following the DKCP iterative process, several workshops and webinars allowed to design new contepts associated with new kind of knowledge.*

2.1 Defining the scope of the concept design

To define the scope of the concept design, a first workshop was held the 5th of February 2020 in Brussels: it aimed at formulating the core values of an organic cultivar trial network from a farmer's point of view. Why choosing this point of view? Because farmers are central actors of cultivar trials, so it is important to understand their reasoning, how they make their choices, and what information they need.

This workshop allowed defining the properties of a "good variety" from the farmer's point of view. The workshop revealed that regardless of the kind of crop (arable or vegetables), a "good variety" is a variety that can meet:

- Consumers' and market expectations;
- Local pedoclimatic conditions and agricultural constraints;
- Social, ethical and cultural values.

In addition to these properties, some thematic values linked with the 4 principles of Organic Farming (cf. Box 2) were also raised: fairness, care, ecology and health. "Fairness" highlights the importance of the relationship between stakeholders, risk and benefit sharing, and transparency of information. It is essential to include a social dynamics perspective (confidence, sharing and community) in the organisation of a trial system?. "Care" invites to consider the precaution principle, regarding natural resources scarcity and respect for the integrity of living organisms. The "ecological" dimension refers to sustainability, recycling, carbon footprint, aiming at achieving systems of food production that

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combine ecology, ecosystem services, diversity and low external inputs. Finally, "health" relates to the environment, as well as to food, people and animals.

Box 2 - The 4 principles of Organic Farming according to IFOAM OI

Principle of Health: Organic agriculture should sustain and enhance the health of soil, plants, animals, humans and the planet as one and indivisible.

Principle of Ecology: Organic agriculture should be based on living ecological systems and cycles, work with them, emulate them and help sustain them.

Principle of Fairness: Organic agriculture should build on relationships that ensure fairness with regard to the common environment and life opportunities.

Principle of Care: Organic agriculture should be managed in a precautionary and responsible manner to protect the health and well-being of current and future generations and the environment.

https://www.ifoam.bio/why-organic/shaping-agriculture/four-principles-organic

This analysis allowed identifying several pathways to be explored. What would it mean to:

- Look at varieties' potential or capacity instead of varieties' performance?
- Launch frugal on-farm testing?
- Think about a decentralised organisation?
- Make trials without statistical evaluation?
- Develop new skills for a frugal cultivar trialing network?

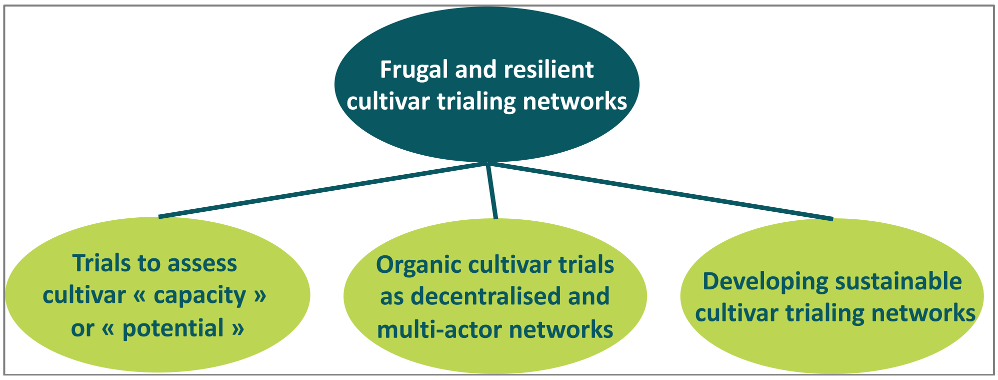

***Figure 6** : Projector concepts in the C-K tree formulated after Workshop #1*

To organise the exploration in the second workshop, three projector concepts were formulated (Fig. 6). Each of these three projector concepts includes several dimensions.

Concept 1 - Trials to assess cultivar "capacity" or "potential":

- Empowering farmers (to test/choose cultivars): how to increase famers' power of action, and through which information? at what time?

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- Providing information instead of recommendation: which information? Through which communication channel?
- Possibilities offered by seed: assessing their potential instead of their performance – which new evaluation criteria or process to consider?

Concept 2- Organic cultivar trials as decentralised and multi-actor networks:
- Shared values, governance across diverse local groups / sub-networks
- Transparency, equity and capacity building
- « Citizen science to support the network »
- Various scales to consider

Concept 3 - Developing sustainable cultivar trialing networks:
- Sustainable from a social, economic and ecological point of view
- Assessing cultivars' full values based on technical, social, economic and ecological criteria
- Sustainable and resilient networks
- Low carbon ecological footprint trials
- Financing issues, frugal innovation
- Trials as provider services
- Risk sharing

2.2 Knowledge sharing to feed the concept design

To feed the second workshop, which was planned to focus on « organic cultivar trials as decentralised and multi-actor networks », we introduced new knowledge (phase K) through two webinars (held on the 3rd of September 2020).
- **Experimental designs and statistical methods for decentralised on-farm breeding** - Pierre Rivière (Mètis)
- **How can citizen science be applied for cost-efficient organic variety testing in Europe?** – Jacob van Etten (Alliance Bioversity-CIAT)

To complete the knowledge provided by the two first webinars, a third one was organised after the workshops (4th of November 2020) to stimulate thoughts about the outlook and opportunities for the future:
- **Presentation of the SeedLinked tool and initiative** by Nicolas Enjalbert (CEO). SeedLinked, an emerging collaborative data sharing platform in the USA, aims to connect people and data to help characterize, breed, and source the best seed. It seems a particularly useful tool to facilitate collaborative trials with real-time information shared among users (farmers and breeders/trialing organization). This webinar aimed at providing another concrete experience, outside of Europe, of a decentralised network. Moreover, SeedLinked was mentioned during the workshops as an interesting tool that could be adapted and used in Europe in the future.

Experts were chosen based on their specialised scientific knowledge or on their empirical experience. Their inputs and the questions these raised aimed at challenging the current vision of the problem. Experts were briefed ahead of the webinar by members of the steering committee.

Through these webinars, the objective for participants was to identify:

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- how does this knowledge provide a "food for thought" towards the organisation of organic cultivar trial networks?
- how are the current technical aspects being challenged?
- how could the role of stakeholders change or evolve?

Figure 7 - *Webinars organised to provide external knowledge (available on replay on LIVESEED website: https://www.LIVESEED.eu/tools-for-practitioners/videos/webinars)*

2.3 Designing an innovative model of decentralised and multi-actor networks

The second collective workshop (phase C – Workshop #2) aimed to explore the innovative concept «organic cultivar trials as decentralised and multi-actor networks». Workshop #2 was organised by ITAB on the 23rd and 24th of September 2020 and involved several LIVESEED partners (Aegilops, Bingenheimer Saatgut, Centre for Agricultural Research of Hungary, FiBL Europe, ITAB, Louis Bolk Institute, ÖMKi, Organic Research Center, Rete Semi Rurali, SEAE – NEIKER, SEGES). The combination with the scenario method allowed participants to imagine the future in a contextual frame (cf. the yellow track on Fig. 8). More precisely, we asked the group to design an organisational network which is decentralised, where the information is produced by multiple actors, where criteria are linked to a diversity of situations and where trials are implemented on-farm by farmers themselves. The related scenario is described in Box 3. We also decided to work in the frame of the "Frugal Innovation" concept (as an introduction to the Workshop, a short video on this issue was presented and discussed with participants : https://www.youtube.com/watch?v=cHRZ6OrSvvI&feature=youtu.be). The first question addressed was "Why are our current models not frugal?".

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Due to the Covid-19 pandemic, this Workshop#2 was organised online. Partners' inputs were collected by using the "Google Slide" tool, where each question was reported in one slide and each participant was able to write his/her own ideas in as box with his/her name as a "virtual post-it". This worked perfectly well as its very simple and easy to access through a single link (no account was needed). After the first step on the Frugal Innovation concept, the questions displayed in Box X5 were addressed one after the other. The outcomes and results are presented in the next chapter of this report.

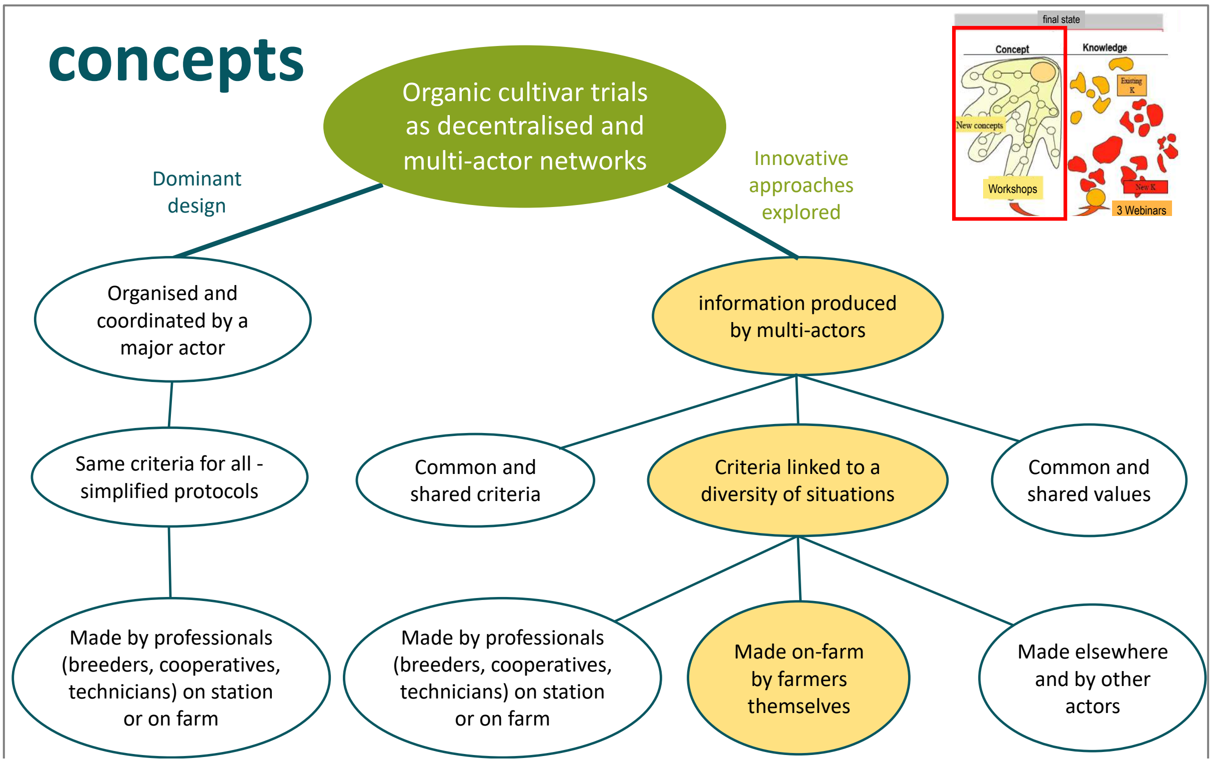

***Figure 8** : Innovative concepts and the scenario to be explored in a C-K tree*

Box 3 - Scenario and questions explored during Workshop #2

<u>*Scenario*</u>

"Each organic farmer needs information on cultivars in order to choose those that are best adapted to his/her own farm specific practices, pedoclimatic conditions, and markets. Considering this, each farmer wishes to test a minimum of criteria of interest to her/him (e.g. competitivity, baking quality, productivity, etc.).

Farmers can measure some criteria on their own, but not all of them. Each farmer agrees to share some observations with the group within the network. He/She sets up the trial with strip plots, with her/his own machinery and preferred farming practices.

The farmer is motivated to participate in a trial network, because it's a way to discover new cultivars, to exchange information on these , as well as on agronomic practices and experimental designs. She/He gets access to the seed needed for the trial.

*As a trial network facilitator, **<u>you</u>** benefit from being part of a group of farms which test varieties in diversified production systems and environments and which have different objectives.*

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The type of data and criteria assessed on-farm vary from one farm to another (as a result they are only partially shared)"

<u>*Questions*</u>
DAY 1 - Focused on the management of on-farm cultivar trials
-As a trial network facilitator, why am I interested in the network?
-What information will I collect and share?
-Should I take individual criteria into account or should I use the criteria shared by the majority?
-Who chooses the cultivars that will be tested (the farmers, the trial/network facilitator, the breeder, collective choice)?
-How is the cultivar choice made, from what type of information?
-Who measures what and how?
-How to manage data from potentially heterogeneous measures?
-Data on environmental conditions and crop management: who collects them and how?
-The control cultivar: What is a control and what is its purpose?
DAY 2 – Focused on the networks, its facilitation, actors and data quality
-How can we define a (trial) network?
-What is the scale of a trial network (geographical but also number of participants)?
-What is the minimum level of facilitation needed for the network to run well?
-What's needed for a network to run properly?
-What are the roles that stakeholders could play in a frugal cultivar testing network?
-Why would people trust the data produced by the network?
-In which case people wouldn't use the network's data?

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3 Results: towards frugal cultivar testing infrastructures for organic agriculture

3.1 The Objectives – Constraints – Methods approach

Based on the outcomes of workshops and webinars described in chapter 2, which brought together researchers from institutes and representatives of the organic breeding sector of several European countries, this chapter presents the concepts and properties of new cultivar testing models for organic agriculture. Following the frugal innovation paradigm, we describe "How to set-up and optimize cultivar testing networks for organic farming?" in a strategy based on three steps:

Define objectives → Identify constraints → Apply a dedicated methodology

- **Defining objectives** is a classical step in the breeding process. In our case, the objectives rely on several key concepts (cf. chapter 1 and 2): GxE interactions, on-farm trials, participatory research and multi-actor evaluation networks.
- **Identifying the constraints** is the key step in our model, acting as the lever to find a tailor-made solution according to the Frugal concept 7 "use constraints as a lever" (cf. Chapter 1). Indeed, most of the existing protocols and procedures are fit for research station trials and not adapted to on-farm trials. These constraints will shape the properties of the cultivar testing model in several aspects: network animation and coordination, experimental design, quality of data management and economic model.
- **Applying a dedicated methodology:** knowing the objectives and the constraints, a dedicated methodology can be applied to design the various elements of a frugal evaluation system, such as network animation and coordination structures, experimental design, data management and quality and the economic model.

This chapter 3 describes the objectives and constraints. Since objectives and methods cannot be presented for each different situation that may exist, next chapter 4 proposes contrasted examples of methodologies based on different objectives and ranging from high constraints to no constraints.

Each stakeholder wishing to set-up or optimize an organic cultivar testing network has his/her own motivations and reasons. However, merging all the motivations of a plurality of stakeholders is a difficult, and often overlooked, political process. As a matter of fact, the gaps left open by current data sources of cultivar evaluation (Chapter 1.2, and 1.3) can be easily interpreted as resulting from a mismatch between the objectives of the breeder, the Authority in charge of registration and the user. Simplifying, we can summarise this mismatch as follows, taking wheat as an example:

- The DUS protocols aim to ensure varietal identity for the application of Intellectual Property Rights on varieties and do not provide information about varietal performance;
- The VCU protocols aim to ensure that new varieties entering the market have improved characteristics compared to existing varieties. Being focused on this new-vs-current comparison, they address few key variables (mainly yield and disease resistance) and require as standard as possible testing conditions;
- Recommendation list trials (either VCU or post-registration) aim to guide varietal choice to serve the largest possible market at a regional/national scale, thus are also focused on yield, disease resistance, quality for industrial processing in non-organic production of commodities;

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– Organic farmers aim at selecting cultivars adapted to their system – which is often specific and different from any other organic farm –, capable of performing consistently over time and/or suited to end-users in local markets, and can barely find the needed information from the results of the above systems.

Fulfilling the needs of organic farmers would require a finer and more detailed information flow. However, this is impossible considering that the organic market is much smaller than the conventional one, unless the objective-setting process is addressed with alternative approaches. In fact, the objective issues can be broken down in two key priorities: (i) an as broad as possible representation of the plurality of needs and aims from a wide stakeholders platform, (ii) an as inclusive as possible process of objectives definition. This means constituting a group that can take collective decisions. Participants are more engaged and motivated when they are associated from the very beginning of the process, including the definition of the objectives. This is a key step and the objectives must be clearly stated and shared with participants: **"what problems is the group facing? What are our goals?".**

As it is impossible to present all the objectives exhaustively (all being dependent of actors, context, crops, etc.), here are some examples of objectives that can be identified by a multi-actor evaluation network:

- to better characterize cultivars and their adaptation to a (greater) diversity of environments and organic farming practices.
- to develop on-farm trials, run with farm equipment and calendar, with simple protocols in order to help farmers to find the best cultivars in their specific context.
- to collect and share high-quality information on cultivar performance or quality.
- to develop on-farm trials facilitating farmers' access to new seed, increasing farmers' autonomy and/or to reducing the time between variety creation and its adoption by farmers.
- to increase knowledge exchange among actors on agronomic practices and cultivars

Once objectives have been defined, a second step is to identify constraints. Considering the higher need for information versus the smaller market size, the methodology of a cultivar testing infrastructure needs to be constituted around the key emerging constraints. In our workshops, four main items arose (Fig. 9):

– **facilitation and coordination of the network** is critical to ensure that a heterogeneous group of actors (farmers, scientists, users, citizens) can consistently and efficiently generate and use the information they each need;

– **experimental design** requires radical innovation, as standard off-the-shelf methods used in mainstream testing infrastructures would be an unmanageable from a cost perspective while generating inappropriate information. A wide series of practical constraints completes the plurality of actors' needs as inputs for the definition of appropriate experimental designs.

– **Data quality management** addresses the need for generating a more inclusive information base, minimising the costs and efforts of data collection, maximising the use-efficiency of different types of data (from quantitative, dominating in conventional infrastructure, to fully qualitative)

– **economic model**, to ensure that cultivar testing can be financially viable as well as act as an opportunity rather than a barrier, to breeding and farming businesses.

In the following sections, the objectives – constraints – methods approach will be described for each of the four above items.

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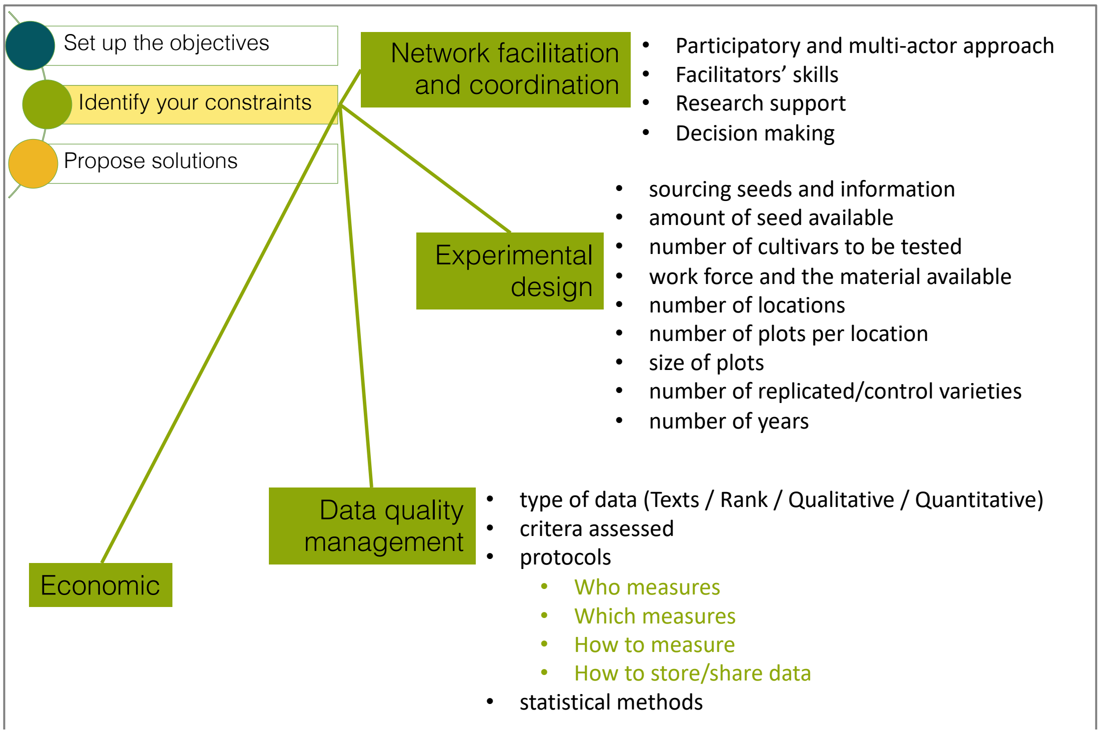

***Figure 9** – Main constraints of a cultivar testing network for the organic sector*

	Specific objectives	Constraints	Methods
Network facilitation and coordination	Generate information relevant to a plurality of contexts and needs	Size of the network Coordination burden Efficient communication	Participatory approaches Facilitation skills and tools Research support for actors' empowerment
Experimental design	Balance reduction in cost and effort with robustness and reliability of results	Seed, Information, Workforce, Number of locations, Time, Resources, etc.	A decision tree of experimental designs and analytical packages targeted to different contexts and constraints
Data quality management	Relevance, Usability, Accessibility of the information	Balance between common and farm-specific information, and between low-cost and effort collection and plurality of variables	Protocols for different data types (from qualitative to continuous), data documentation, data storage, data ownership and governance
Economic model	Self-sufficiency, Value creation, Viability in the long term	Fixed costs, Workforce, Conflicting interests	Public support, User-subscription models, Value-chain cost recovery, Hybrid models, etc.

***Table 1** - Examples of specific objectives, constraints and methods for each of the items identified in the workshops*

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3.2 Network facilitation and coordination

3.2.1 Definition of a cultivar testing network

The first step is to better define what is covered by the term "cultivar testing network" in order to identify its peculiar constraints. A network can be defined as **a set of small autonomous entities interacting with one another and federated by a common entity or purpose**. It is an agile and creative organizational framework evolving in often very complex and changing environments. A cultivar testing network can be non-official or informal, act at a pre or post-registration stage of varietal development, and to act at even earlier breeding stages as part of participatory decentralised plant breeding programmes.

A cultivar testing network can bring together different actors who share common purposes, values, goals, commitment, seed, projects and information. For example, farmers are often driven by a strong desire to learn about each other's practices and experiences, testing and participating in the development of new bred varieties. Everyone in the network should work for the common good, based on a shared agreement.

In a group, each member plays a role and can take several attitude: proactive, reactive, observer, inactive. Whatever the size of the group, proactive are around 1%, reactive (who participate when prompted) are between 10 and 40%, the rest are inactive, some of which are simply observers, meaning that they listen and use information for later (Collectif Cooptic, 2014).

A network has also a strong territorial dimension, because it is often articulated on several scales, from local to regional to national or even international with different roles and objectives (Box 4). The organization of a network must take into account these different scales.

Network size is a critical driver of how the activities can be organised. In fact, there are critical size requirements to be considered:

- **a maximum manageable size.** It is suggested that beyond a certain size (20-30 participants), it is more complicated for network members to know each other, communicate or build confidence. In a group of 12 persons or less, the group can work by itself (Collectif Cooptic, 2014).
- **a minimum size** is needed to manage seed and deliver relevant results. Depending on the size of the network, the volume of activities the coordination efforts (project management, fundraising, partnerships, communication) and facilitation may be more or less substantial.

When working with a group between 12 and 100 persons, a facilitation is needed to obtain reaction. Over 100 members, collaboration can be managed if the facilitation focuses on reactive participants (Collectif Cooptic, 2014).

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Box 4. Examples of different network levels working on peasant seeds at several geographical scales: European, national and local

European scale
The European coordination Let's Liberate Diversity! aims at encouraging, developing and promoting the dynamic management of cultivated biodiversity on farms and gardens. LLD organizes regular meetings between its members. 14 organizations are part of LLD. Most of the knowledge exchanges are in English. www.liberatediversity.org

National scale (within a 1000km distance)
Réseau Semences Paysannes (RSP) in France is a member of LLD. RSP brings together a great diversity of networks and people who preserve framers' seeds in fields, orchards, vineyards and gardens. Nearly 100 organizations are members of RSP. Knowledge exchanges are in French. www.semencespaysannes.org

Local scale (within a 250km distance)
Pétanielle is a member of RSP. It brings together farmers and gardeners with a view to the conservation and development of cultivated biodiversity. It is located in the Occitania region in France. Its activities mainly focus on wheat for bread making but also include other species: barley, oats, corn, vegetables.
www.petanielle.org

A cultivar testing network can be organized around the following activities:
- exchanging and capitalizing knowledge and information (a central platform, meetings, "on-farm trial platforms", training);
- prospecting, conserving (living collections, community seed banks), sourcing and/or distributing seed;
- conducting experimentations, disseminating results;
- managing equipment, infrastructure, material (sowing, harvesting, sorting, storage, etc.).

Finally, the digitalization of data has a strong influence on the organization and functioning of networks: digital tools are more and more used in all sectors of society. On the one hand, it facilitates cultivar testing projects and is an essential tool to manage large testing networks at regional or national levels. On the other hand, it generates less human contact and fewer in-person exchanges: it anonymizes exchanges to the detriment of trust and mutual knowledge between the members of a collective. It also generates asymmetry of knowledge, since those who know how to use the tool end up being more specialised. Data stored in the database and disconnected from the context have no sense if they are not discussed and analysed with farmers.

A significant amount of facilitation must therefore be dedicated to the establishment of rules concerning numeric and data management: e.g. do we need a data-base? What for? Who owns the data? Who has access to the data?

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3.2.2 Participatory and multi-actor approach

When cultivar testing is decentralised on farm, the decision process must also be decentralised: all actors participate to set-up the objectives and the strategies to achieve them. This principle has an impact on network governance, which should be shared as much as possible through the creation of a board gathering all actors and orienting the project. The first decision to be made is to agree on how to decide: it can be done through consensus, consent or vote. Decisions can be related to the objective, the budget, the experimental design, etc.

Participation is crucial: this kind of trial network cannot work properly without it. When the level of participation and inclusiveness is high at each stage of the project, both in terms of decision-making and responsibility sharing, stakeholders are motivated, which contributes to the initiative's success. Farmers' participation in particular is highly important. They must be able to: choose the cultivars[2] they want to work with, define their own selection criteria and the variables they wish to measure. All these parameters should be relevant for the farmers, particularly when they are not paid for the exercise, which is often the case.

This decision-making autonomy favours the involvement and engagement of farmers. In many projects, farmers' participation is limited to the evaluation of varieties selected in research stations and their multiplication. With such an approach, farmers' knowledge is lost and varieties are developed which are poorly suited to diverse contexts.

The fact that technical and/or scientific support has a less prominent role than in the conventional testing systems and that it is more respectful of farmers' decision-making autonomy does not mean that it is less important. In fact, when technical/scientific support downsizes its authority and gives back decisional power to other actors, it acquires the even more critical and active role of ***empowering*** the network to work as autonomously and as efficiently as possible. Scientific/technical support becomes an additional support for the network, upscaling its potential to generate useful information by guiding the definition of common protocols, facilitating peer-to-peer meetings, supporting decision making (for example for variety choice) and data management.

Other actors can be involved in the cultivar evaluation activities: breeders, seed companies, agribusiness companies (upstream and downstream), consumers, gardeners, students, agricultural public bodies, chefs, etc. According to the origins and the motivations behind the emergence of networks, any type of actor can get involved in the governance and/or be an operational partner. Each role must be clearly stated, and everyone should be responsible for the success of the process.

In a multi-actor programme, it is important to mobilise building blocks that structure the collective organization, such as common will, common vocabulary, trust, transparency, facilitation, appropriate distribution of work, etc. (Serpolay and al, 2018). The search for consensus must include the criteria and constraints specific to each actor, which complicates the organizational process and impacts of each stage of the project. This concerns the initial choice of varieties, the objectives and the methodology of the experiment (e.g. the type of data to be collected), the interpretation of results, etc. The idea is to quantify, without minimizing it, the work that must be deployed to reach agreements beyond different visions. Other issues, such as intellectual property rights, are highly important and must be extensively discussed by everyone. Multi-actor programmes are a continuous

[2] In some examples, it may be interesting to have blind tests to avoid any prejudice before starting trials (van Etten J, et al, 2019).

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and iterative process based on mutual learning (Serpolay and al, 2018), the results of which are both in the process and in the end products.

Working in national or international projects is not without consequences in terms of participation: for example, the hierarchical division of tasks required by the complexity of multi-partner projects has a negative influence on the participation of farmers and the co-construction of knowledge. Thus, the level of participation is often inversely proportional to the size of the project. One of the challenges is therefore to preserve the qualities of the work in the territorial networks, at a level allowing good mutual knowledge, regular physical meetings on farms, and the formalization and implementation of common rules.

	Cultivar prospection & information	Conservation Pre-multiplication	Multiplication	Selection	Material	Experimenta-tion/ Evaluation	Dissemina-tion/ communi-cation	Funding	Decision making
Facilitator/ technician/ Advisor	x	(x) seed bank management, vitrine management			(x)material manage ment	x	x	x	x
Farmer	x	x	x	x	x	x	x		x
Researcher	x			x	x	x	x	x	x
Breeder	x			x	x	x			x
Seed companies	x		x		x			x	x
Food chain actor				x		x transformation processing	x	x	x
Consumers				x		x (organoleptic)		x	x
Gardeners	x	x					x		x
Teachers/ students					x	x	x		x
Phytosanitary experts/ authorities						x			x
Government			x			x	x	x	x
Farmers organizations					x	x	x	x	x
Agro-tourism guides							x		x
Chefs	x			x		x (organoleptic)	x		x

***Table 2** - Example of stakeholders' involvement in cultivar testing network and possible roles*

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3.2.3 Facilitators' skills

Facilitation involves specific soft skills aimed at promoting participation and collective intelligence: interpersonal skills, sociability, very good listening skills, autonomy, impartiality, speaking in audience, oral and written fluency, ability to work in a team, mediation ability (by reformulating, translating, simplifying), conflict management, adaptation, practicality (See an example in Box 5). The facilitator also needs to have knowledge of participatory approaches and tools, their practical application and the ability to choose the most appropriate methods according to the contexts and objectives.

Concretely, a facilitator supports the reflection of the collective by helping it to formulate its objectives and rules, to define its orientations and formulate questions and appropriate answers. He/she makes sure that the group's values and purpose are respected and met and facilitates the distribution of responsibility. Facilitation becomes essential if a conflict arises which needs to be managed. The facilitator can also regulate how and when members can enter into or exit from the group, performing an essential mobilization role.

Box 5. Meeting facilitation: role and skills of the facilitator

Role of the facilitator:

- Facilitating exchanges: question, rephrase, reframe, bring out a proposal, consolidate it and formulate it orally and in writing (report)
- Allowing everyone's possibility to express their views: distribute and regulate speaking times
- Guaranteeing the smooth running and respect of the initial set of objectives, refocusing the debate
- Managing group dynamics (observe, detect changes in atmosphere / group reactions, keep an eye on the audience rather than on the speaker, analyse the reactions and facilitate the outcome).
- Be the timekeeper, and when necessary give more time or restrict it depending on what the programme and schedule allow (in collaboration with the group).
- Meta-communication: give the group a sufficient level of information, by providing examples and clarifications to contextualize a message and therefore helps to understand a situation.

Skills of the facilitator:

- He/she does not need to be an expert on the subject, but must allow the flow of speech, collect ideas and proposals, regulate exchanges, reframe if necessary, also know how to step aside if the debate is self-sustaining.
- He/she has to be careful managing his/her own emotions as a facilitator: he/she must welcome all inputs equally. The facilitator must be objective and neutral, to promote the group's free expression. He/she plays a protective role: guaranteeing respect for everyone's voice (freedom and fairness in speech time, tolerance for the diversity of points of view, etc.).
- Still from a technical point of view, the facilitator may also have developed skills related to project management (logical framework, budgeting, project formulation, fundraising, monitoring / evaluation, reporting)

The facilitator seeks to bring out new ideas by organizing meetings and exchanges that will be a new source of propositions and ideas. He/she helps to collect, centralize and capitalize the information, stories and knowledge that emerge from the collective and disseminates it in an appropriate manner.

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The facilitator should not take the place of its members. He/she must be able to be a mostly autonomous catalyst of proposals, but always capable of making alink with the members of the collective and avoid validating the final decisions alone. By feeding the group's reflections, he/she actively participates in its decision-making process but has no power to make any decisions. It is not his/her wishes that he/she carries, but those of the collective. Respecting this code of ethics remains a challenge, particularly in multi-partner projects, where technical nature of some projects can have deleterious effects on the role of the facilitator's, who risks becoming simply an expert. An appropriate and well designed governance structure can include strategies to limit this risk.

In participatory research, it is not enough to bring actors such as researchers and farmers around the table. The facilitation objective is to take into account the knowledge system dissymmetry and to strive for epistemic equity, particularly between farmers' know-how and scientific knowledge. It is important to focus on knowledge sharing during the process, using facilitation tools as well as an adapted language which is technical enough but easy to understand. A space for knowledge sharing based on different types of communication can be proposed, for example field or lab meetings.

As for cultivar testing networks, facilitation can also cover technical, scientific and agronomic dimensions. In connection with varieties and seed management, it may involve organizing seed exchanges, ensuring the quality of seedlots, stocks storage and conservation etc. The objective of this support is for example to take into account each actor's criteria, which can be very diversified across the different fields and sectors in which each actor operates: the facilitator must lead to a consensus on the characteristics to be observed in the trials, to meet all actors' priorities (for example in the case of cereals straw, breeders and bread wheat producers will have different criteria and objectives). Facilitation will also favour a reflection among partners on the experimental protocols to be put in place, the establishment and monitoring of trials, the characterization of varieties, plants, data recording, analysis and processing, the capitalization and sharing of the resulting knowledge, the coordination of actions, etc.

One of the challenges in terms of facilitation is to take into account the producers' limited time availability: this means working in restricted geographical areas (less travel), but also compensating the time producers spend on the trials or during collective tasks (for example to maintain a collection of several dozen of varieties by paying them). Even if regular meetings with partners are important for the network's cohesion and to obtain feedback from the trials, it may be necessary to minimise the impact of meetings on farmers' busy schedule and organise the meetings calendar based on the agricultural/crop calendar. Meetings can represent the opportunity for producers to have a central role, by setting up experience sharing possibilities. For instance, it can be interesting to implement a field day where scientific and technical knowledge can be shared with farmers to ensure it is a relevant and meaningful integration to their know-how.

Communication – within and outside the network - is also an important role for facilitators. Information about the results of trials, invitations to meetings, training events should be communicated through newsletters, websites, mailing lists, articles in local or regional newspapers, etc.

All or part of the facilitation work can be carried out by paid staff from producers' groups, technical or research institutes, but also by external service providers or by a farmer with institutional responsibilities within his group and who has the time and skills. Some facilitators may have hybrid

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routes: for example, the facilitation of a producers' meeting can be assumed by a researcher. Facilitation undertaken on a voluntary basis within the collective and facilitation carried out by salaried staff or even supported by a partner or a federative entity, can have a significant impact on local networks in terms of action capacity, participation level, collective autonomy and responsiveness (Box 6). Given that the objective pursued by facilitation is the emergence of a cooperation culture, it can be very relevant to train the internal actors of the network to pick up some facilitation tasks and roles, thus developing the group's skills on these subjects.

Box 6 - Examples of facilitation types and organisation characteristics

	Action capacity	**Participation level**	**Collective autonomy**	**Reactivity**	**Tendency to centralization**
Example 1. Volunteer facilitation (e.g. association combining volunteer citizens and farmers)	Limited	Strong	Strong	Low	Limited
Example 2. Direct facilitation by paid staff (e.g. Employee from a producer's group)	Strong to medium	Medium to low	Medium to low	Medium	Strong to medium
Example 3. External facilitation (e.g. staff from a national or regional network)	Strong to medium	Low to very low	Low	Strong to medium	Strong

Challenges in terms of participation:

Example 1. To avoid the volunteers' exhaustion, to promote the mobilization and transmission of skills to ensure turnover. These collectives are characterized by great autonomy and a high level of participation. Their ability to develop new actions or deploy existing ones, on the other hand, is more limited.

Example 2. To mobilize producers and partners around a common goal to build a shared project and to identify a minimum action base that can be implemented with limited financial resources.

Example 3. To get as close as possible to the field (meetings on farm, partnerships to decentralise actions through smaller local networks), to avoid the pitfall of excessive centralisation in decision-making as well as in terms of the circulation of seed, information and knowledge.

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3.2.4 Vigilance, recommendations and take-home messages

Facilitation and coordination are cornerstones of the network, and a few issues have to be kept in mind:

- the size of the group has an impact on its functioning
- a cultivar testing network can bring together different actors around common purposes, values, goals, commitment, seed, projects and information
- include as many actors as possible (from farmers to chefs, citizens, etc.)
- common vocabulary and trust are important to discuss and build something together
- democracy and transparency are needed in the decision process
- regular physical meetings can foster exchanges and build new knowledge
- digitization and ownership of data needs to be discussed and rules set-up

Facilitators must possess different skills in order to promote participation and collective intelligence:

- soft skills, such as sociability, listening capacity, autonomy, impartiality, ability to work in a team, mediation, conflict management, adaptation and flexibility
- technical skills such as scientific, agronomic, oral fluency and written expression, project management, communication

An important constraints to effective facilitation for our context is the lack of dedicated training that encompasses the complexity of the different skills required. As facilitation is central in the multi-actor process, investing in it is a priority. Another issue may be the availability of a research team to support the network with methodologies, tools and/or technical people. Without it, it may be difficult to benefit from the scientific base for designing appropriate trials and for accurate data management and analysis.

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3.3 Experimental design and analysis

Before sowing, it is important to well define the objectives and the experimental design of the trial, as well as the data analysis method and strategy.

The constraints are linked to the experimental design and not so much to the data analysis methods: indeed, various statistical analyses are available to cope with many designs (Goldringer and Riviere, 2018) and do not require specific computing facilities.

First of all, the objectives will have an impact on the experimental design. The main objective in a cultivar testing network may be to determine which cultivar(s) performs well in a farm in a given context. This main objective can be divided into several sub-objectives to better understand the cultivar's behaviour, for example (Goldringer and Riviere, 2018):

- To improve the prediction of a target variable for selection through the analysis of agronomic and nutritional traits and of the link between functional traits and farmer management (Martin and Issac, 2018)
- To assess variety capacity and adaptation by studying GxE interaction and local adaptation (Blanquart et al, 2013; Gauch et al, 2008)
- To compare different varieties or populations evaluated for selection in different locations through an analysis of agronomic and nutritional traits and sensory analysis (Rivière et al, 2015; Rodrıguez-Álvarez et al, 2016)
- To study the response of varieties or populations under selection over several environments through the analysis of agronomic and nutritional traits (Gauch et al, 2008)
- To study seed circulation networks through analyses of network topology (Pautasso, et al, 2013)

Once the objective is defined, relevant experimental designs can be chosen. These may face several logistic constraints:

- ***Sourcing seed***. The first step is to source seed as well as related information. Seed can be sourced from genetic resource centres, local farmers' groups such as community seed banks, or from the market (national or foreign). Information on varieties is important, for example regarding the climate conditions to which they are best adapted, on their disease resistance, their genealogy and history, germination rate, farmers' and/or breeders experience with it, results from other trials. Information can be retrieved through bibliographical research or thanks to the organisation of peer-to-peer exchanges where experienced farmer-breeders can share their knowledge and know-how in a suitable framework. Field meetings are an interesting tool for facilitating his type of knowledge exchange. Internet for a bringing together farmers, technicians and researchers organised and moderated by a national organization can also promote access to varieties and associated information. Collecting as much information as possible may prevent the network from having to test too many varieties.
- The ***amount of seed available*** is one of the main constraints, and will have an impact on the number of plots, their sizes, the number of replications, etc.
- The ***number of varieties*** depends on sourcing and amount of seed available. The set of chosen varieties must maximize phenotypic diversity within and between entries: having many varieties does not necessarily mean that they represent a lot of diversity (Bonneuil et al, 2012). Exotic varieties (i.e. varieties coming from very different climate area or countries) can also be interesting to test. Several types of varieties exist and present a gradient of diversity: pure lines, landraces, crosses, mixtures, and others (Goldringer et al, 2017).

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- The ***work force and the material available*** to carry out the trials will have an impact on the number of plots and their size, because of the labour and material intensity of phases such as sowing and harvesting. It will also have an impact on the type of data collected.
- The ***number of plots per location***. Farmers may not have a lot of space to devote to trials. In addition, more plots means more work, and without much technical support it is complicated to devote sufficient time to appropriately manage the trials.
- The ***size of the plots***. This is linked to the amount of seed available and the materials available for sowing and harvesting. Most of the farmers do not have specific plot-scale machinery and hence will rely their routine machines and infrastructures: for example machines that sow 3 meters large strips and harvest 6 meters strips (Cerere project, 2019). Contrary to other constraints, the size of the plot does not have any influence on the analysis methods used. Nevertheless, larger plots are better to assess yield, especially in organic conditions (Kravchenko et al, 2016).
- The ***number of locations*** is directly related to the number of participants and supposes a strong coordination, as described in the previous section. In decentralised selection and evaluation, the number of locations should be large enough and cover the main growing area of the crop to fit to the reality as much as possible. The farmers should use their own management practices. A mix between research stations, and experimental gardens and farms is another possible option.
- The ***number of replicated varieties*** within and between locations to measure variability. For a given number of plots, farmers often want as many varieties as possible and generally do not want to "lose" plots by replicating the same variety. The importance of having control varieties to produce reliable results must be highlighted during the participatory process. The control can be a variety for which a lot of data is available, for example coming from official trials, or a variety which is widely known and cultivated by the farmers within the network. Two levels of controls can be used: one control used by all the members of the network and other local controls used in locally based on geographical, or pedoclimatic properties. The control has a statistical function as well as a sociological one: it is a topic to discuss when organizing workshops with farmers (how the control behave on different farm based on empirical observations).
- The ***number of years.*** It is important to evaluate varieties over several years, as yearly variations and interactions between varieties and years are important factors. Results from one year trials cannot lead to definitive results but can raise hypothesis for future years. Time can be used to compensate for space, by dividing varieties over several years whenever it is not possible to sow all of them in a trial at the same time. Number of locations can however compensate number of years.

These constraints are intertwined with other constraints related to data collection. Data analysis can be performed on homogeneous data, for which the variables have been measured with the same method. Meta-analyses such as rank analysis (Brown and al, 2020), can deal with heterogeneous data. The list below present four types of data from the easiest one to collect (low constraints), to the most difficult one (high constraints):

- ***Text and purely qualitative data***: Each farmer gives a written description of each variety for one or several traits, for example disease or yield. This approach does not require detailed protocols and is very easy to apply without any specific facilities. Field visit can be organized several times a year to exchange information on varieties' performance and enrich farmers' information. At the end of the growing season, workshops are organized to share participants' observations based on their notes taken during the year. Animation in groups can be done (e.g. word café) followed by a plenary session. If no funding is available and stakeholders are from different regions, digital tools may be used.

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- ***Ranks***: Each farmer gives a rank to each variety for one or several traits, for example disease, yield, or in general (which variety do I like the most?). This approach does not need detailed protocols and is very easy to apply without any specific facilities. Adapted analysis such as the Plackett-Luce model can be used (Van Etten et al, 2019).
- ***Ratings***: Each farmer or facilitator measures a qualitative trait following a dedicated method and protocol, for example rating/scoring from 1 to 9. It can be facilitated by e.g. pictures, to allow different observers have the same reference: how does a score 5 look like. Multivariate analysis can also be proposed.
- ***Quantitative (continuous) traits***: Each farmer or facilitator measures a quantitative trait following a dedicated method and protocol. Dedicated methods to cope with incomplete and disequilibrium design exist (Rivière et al, 2015; Rodriguez-Álvarez et al, 2016). Multivariate analysis can also be proposed.

Knowing the objectives and constraints, a tailored methodology can be chosen. Most of the protocols and procedures fitted for research station trials and widely spread are not transferrable to on-farm trials. As an example, the analysis of variance (ANOVA) is frequently used on experimental sites to compare varieties. However, it requires a large number of plots and replications, which are not usually possible in on-farm trials managed by farmers.
To select the appropriate method that fits with a certain situation, the following decision tree (Fig. 10) is proposed, based on the objective "comparing several cultivars evaluated in different locations through the analysis of agronomic traits". Several experimental designs are proposed based on types of data and constraints, for instance i) the number of plots per location (= number of cultivars to test), ii) the number of locations (= number of farms involved) and iii) controls and replications. For each kind of analysis, a scientifically validated method is proposed.
To sum up, Figure 10 shows that for many constraints, there are statistical methods that can generate robust and useful data for decision-making. To illustrate how these methods can be implemented, concrete examples and outputs are presented in chapter 4. "Apply a dedicated methodology".

As Serpolay et al. (2018) mentioned, if there are too many constraints in the experimental design and too many data collected, only few farmers will be able to get involved. In that case, data return may be slow and low, results shared too late, and in the end, trials will have a low efficiency and impact. To work around this issue, simple designs should be proposed, in order to involve as many people as possible and increase participation.
In a participatory approach, the method for data analysis must be chosen through a discussion involving all the actors. While analyses are based on validated scientific protocols and methods, researchers often distrust non replicated on-farm field trials. A transition period seems needed to allow "official" institutions to accept and recognize novel data collection and analytic approaches appropriate for decentralised on-farm trials.

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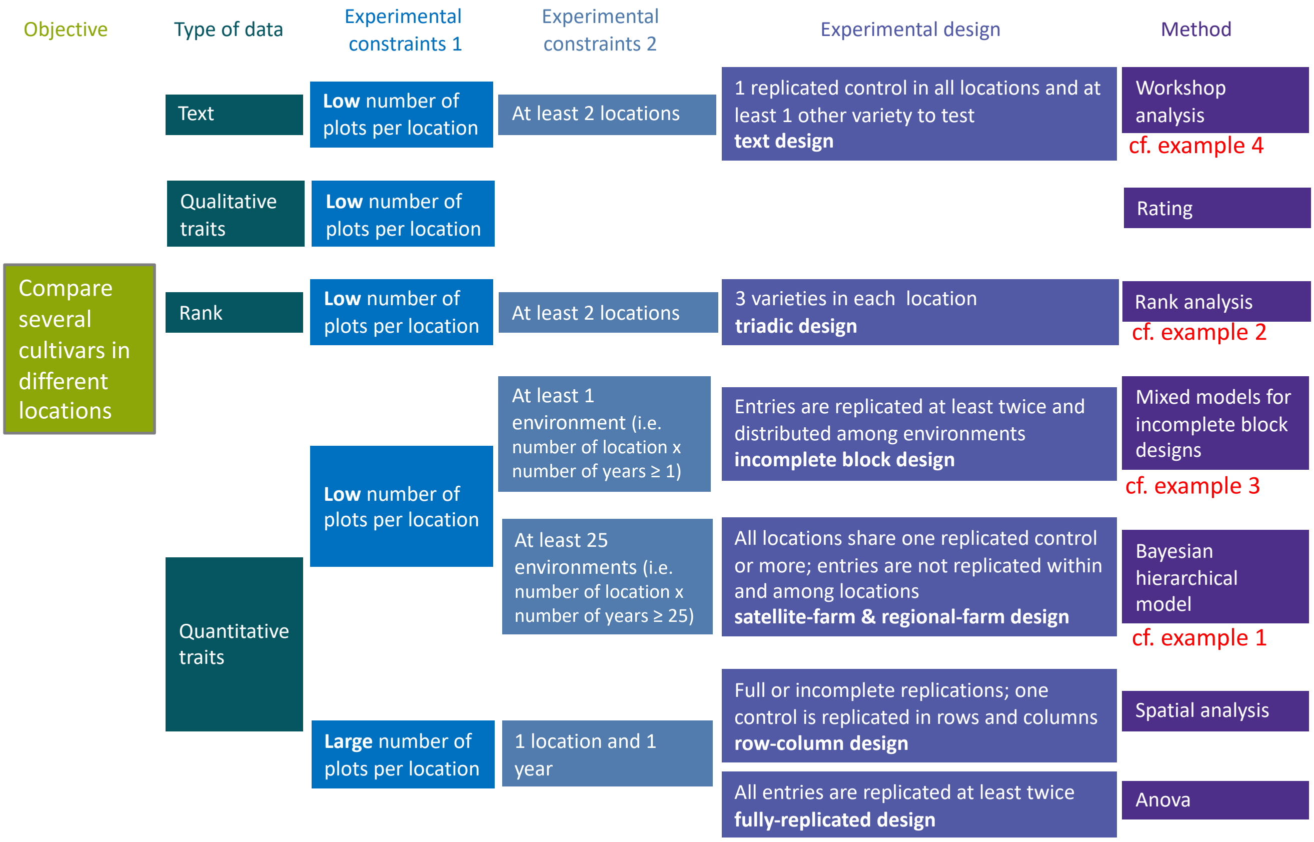

***Figure 10** - Decision tree adapted from PPBstats (Rivière et al., 2019): for many constraints, there are statistical methods that can generate robust and useful data decision-making.*

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3.4 Data management

Once the experimental design is settled, the next step is to collect the data. The nature of data collection depends on the objectives and faces several constraints. The key point is to answer to the following questions: what kind of data am I able to produce? And can we trust this data?

Several kinds of data can be produced related to:
- people: the general data protection regulation (GDPR) at the European level and good practices such as informed consent must be considered.
- history of seed lots (location, person who produced it, year, variety, relation between seed lots)
- knowledge, information on varieties
- environment (climate, soil, local practices, etc.)
- raw or processed data
- traits: crop phenology and morphology, interactions with the agroecosystem, production, quality (Fig. 11)

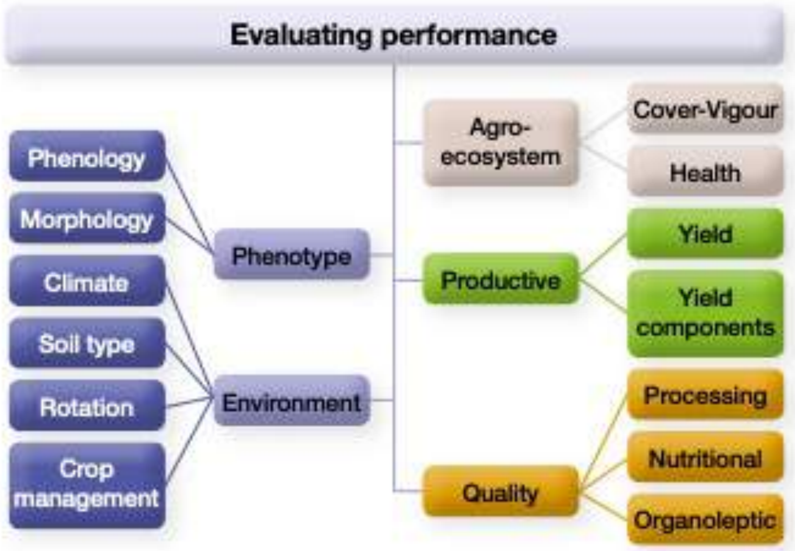

***Figure 11** – The different aspects of crop performance evaluation (right-hand side) and examples of the key predictors of performance that it is essential to record (left-hand side) (Costanzo &Serpolay, 2019 – DIVERSIFOOD project)*

While most of these data produce scientific knowledge, some produce local and empirical knowledge. These two kinds of knowledge are complementary and must feed into each other.
The members of the network will trust the data if they know who takes the measurements and how (everyone will trust their own collected data!), they agree on the protocol, they know how it is stored and they agree on the rules regarding data management. It is important not to collect data alone but in a dialogue between actors in a transparent and participatory way. Trusting the data can be linked to the quality of the data:
- the data should be collected through a relevant experimental design as described in the previous section;
- the variables must be relevant, i.e. useful to reach the objective and make sense to farmers;
- the data must be measured with rigorous methods and protocols;

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- the data must be stored in a comprehensive way.

The quality of data is central. If the data are not reliable, then the analysis makes no sense, and all the work can be considered lost.

Regarding protocols, several aspects are to be taken into account:

- **Who measures?** An important point is to agree on protocols leading to high quality data. Different people may measure different variables based on the level of technicality: farmers will not measure the same variables as researchers. It is always important to agree on how to measure: this can be done through dedicated training, for example to agree on how farmers should measure yield. It is a way to create standard protocols. Some data, which are more technical or need time or material (such as protein content, quantitative traits, diseases, weed presence) can be taken by facilitators/technical people.
- **Which measures?** A balance can be found between common and individual criteria for each farm. Common criteria must be easy to assess/collect by everyone, whatever constraints exist. These can be seen as part of a standard evaluation agreed by consensus and shared by all the members of the group, and should be based on few criteria and be mandatory. Common criteria can lead to the evaluation of a sort of comprehensive "value for cultivation" which allows an overall ranking of the trial entries. Individual rating, that can be made on a local geographical zone, will improve and enrich the knowledge of the local community. It can be linked to a product, a market or a specific management approach. When it is not possible to measure many traits, the group should focus on important criteria such as yield. There is a distinction between traits that need to be measured only once and others which require repeated measures at several stages during the growing season. Criteria are detailed in chapter 5 of this deliverable. Other criteria can be found in existing databases such as ontology (Jonquet et al, 2018). Resetting the list of variables every two or three years can be a way to start new discussions based on new results, observations and objectives.
- **How to measure?**
  - Clear protocols and documentation (texts, pictures, photos) must be defined to control the quality of the data and avoid heterogeneity. However, some argue that protocols must be as simple as possible with almost no documentation such as for example scoring the taste between 1 and 5. The protocols must follow scientific standards and be validated by all actors, especially farmers that run the trials on their farm, in a participatory approach. Protocols can be inspired by or shared from official registration procedures. When the workforce and the trial material are a constraint, the protocol should be as simple as possible.
  - Heterogeneity of data can be of two types: there can be different variables, or same variables but different measurement methods. Before the growing season, time must be devoted to agree on the protocols: criteria should be clearly decided beforehand. Variability linked to the person that measures can be high and a common training session to agree on a common protocol will reduce this variability.
  - Metadata are important to evaluate data quality: how each observation has been measured. When several data come from the network, it is then possible to filter unreliable data out, or group them by comparable methods.
  - Measures will depend on the type of data (cf. Fig. 10): the two first (rank and text) are the easiest ones and may be the simplest way for farmers to do measurements while the two last (qualitative and quantitative) need more work on protocols.
    - rank: this data type allows dealing with heterogeneity of data.

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- texts: farmers have great knowledge about cultivating the varieties. Each farmer can write down some text to describe the behaviour of the varieties in a notebook. Interviews can also be a good way to collect information.
- qualitative (scoring, e.g., 1 to 9): the measurement can be done in the field. It is also possible to organize a meeting to collectively make measures.
- quantitative: the measurement can be done in the field or in the lab, depending on the variables. It is also possible to organize a meeting to collectively make measures.
- environmental data: In this case, it is important not to forget to use historical data, for example, by consulting climatic data base for the closest station to the farm, asking for the results of soil analyses already performed by farmers, and searching for GPS information linked to existing databases.

– To get high quality data, this protocol can be followed: (Bertil-Equille, 2004):

- Get prepared for data collection: set objectives, a timetable, establish who does what, clarify the nature of the data required, prepare forms and protocols and develop methods to detect errors, establish who has the right to use the data, ownership and access issues, etc.
- Start data collection
- Monitor data collection
- Enter the data in files or in a database
- Check the consistency of the data and possibly correct them
- Assess how the process worked

These different steps take time but are essential to have clean and reliable data. A centralized quality assessment can be an efficient solution. In all cases coordination of data management is crucial.

Regarding storage, data must be stored in a straight forward way in order to facilitate the analysis and sharing. This allows anyone to go back to previous experiments and to easily find information.
Organized data create a database. All kind of information can be stored: raw data as well as analysed data that valorise network information (heritability, GxE, groups of farms, etc.). Accessing data and visualising it in an interactive way can support evaluation and encourage participation.
Several databases to manage network trials already exist (De Oliveira et al, 2020; www.kobotoolbox.org; www.seedlinked.com) and can be linked to other databases that store information such as criteria (Jonquet et al, 2018), climate[3] and soil[4] through GPS coordinates, *ex-situ* accessions through EURISCO[5], etc. Regarding soil data, it is more reliable to look at local scale data and cross information with owners who know their field well.

Common databases can be used to facilitate information sharing. The use of a database is easier if a facilitator manages it and ensures the respect of data quality protocols. At EU level it seems important to have robust data that can be transferred, but there is a language barrier and specific IT solutions are needed.

[3] https://cds.climate.copernicus.eu/#!/home
[4] https://esdac.jrc.ec.europa.eu/resource-type/european-soil-database-soil-properties and https://land.copernicus.eu/global/products/swi
[5] https://www.ecpgr.cgiar.org/resources/germplasm-databases/eurisco-catalogue

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3.5 Cost management and value creation

Cost management and economic sustainability are practical constraints that should be considered in developing innovative cultivar testing strategies for the organic sector.

Participatory cultivar testing requires continuity over several years and involves costs related to human resources, field trials, quality analyses and physical facilities. Long-term investment is needed to allow fruitful exchanges and debates upstream in order to build trust between the partners, to formulate shared objectives, language, protocols and field observation criteria, to agree on the type of data to be collected and their processing, as well as to discuss the results obtained and disseminate them.

LIVESEED has evaluated currently active organic cultivar trial networks across 15 countries in Europe based on different criteria, including their financial model (Kovács and Pedersen, 2019). From this analysis, it emerged that the current organic cultivar trials are based on one or -more commonly- on a combination of financing strategies, as summarized in Box 7. However, the current funding models are often fragmented and the continuity in time of the trials is not guaranteed. A LIVESEED report (Kovács and Pedersen, 2019) highlighted the weaknesses and threats determined by these financial issues of many of the explored cases.

Box 7 - Financing models of current organic cultivar testing financing (more info in Deliverable 2.1)

- 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).

The issue of how to finance organic cultivar trials is part of the more general problem of how to create a strong and independent organic breeding and seed sector. In fact, the financing of organic breeding as a whole still remains a challenge. There is a wide consensus in the Organic Plant Breeding (OPB) community that the refinancing through royalties or seed sales – a business model common in the conventional breeding sector and also applied in Breeding for Organic programmes - cannot be easily applied to their context. In fact, the main income driver in such model is the acreage covered by an individual variety. This is intrinsically in contrast with the aim of Organic Plant Breeding, which is to breed for many different crops (including minor and neglected crops) and to produce highly diverse, locally adapted cultivars. Additionally, several OPB initiatives reject the application of variety protection, since their vision is to maximise free access to genetic resources.

LIVESEED aims at facilitating the debate on current and alternative financing strategies for organic breeding and proposes a diversified strategy that includes public funding and private donations together with resources from value-chain based partnerships (Nuijten et al., 2020. Topic 5).

Various attempts have been made at small scales to ensure that organic breeding initiatives do not depend solely on public funding or private donations. Sector-wide collaborations allow for a more fairly distributed financial burden among the different players: breeders, farmers, other practitioners (cooks, bakers, etc.) and across the value chain, including the final sales points. The development of organic food systems where the different actors of the organic value-chain take into account the cost

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of organic breeding is highly promising, especially if organized as an overarching pool funding strategy for the whole organic breeding sector (Box 8).

Box 8 - Pool funding strategy for organic breeding in Europe (more info in Deliverable 3.5, Topic 5)

Given the success factors that could be deduced from the mapping of the current experiences of financing breeding with collaborations along the value chain, LIVESEED activities helped to summarise the opportunities for integrating organic breeding in value-chain partnerships.
What emerged is that the development of a **pool funding strategy for organic breeding in Europe** could serve as a central pillar for the financing of the different organic breeding organizational models (including participatory plant breeding).
The central concept of the pool funding strategy is that all value chain partners of the organic sector should make a collective effort to invest in organic breeding. If a small part (e.g. 0.1- 0.2%) of the turnover from the sale of organic products were collected into a pool fund, it would boost the growth of organic breeding and allow a high-level collaboration within organic sector. Revenue from this pool fund could then be distributed to individual organic breeding initiatives. An alternative could be that various chain actors carry the responsibility for different steps of the breeding process. This however needs very careful coordination and communication to keep all actors involved over time.

Considering the specific aspect of cultivar testing, understanding the relationship between the costs and the value of such activities to the actors involved and in general to the organic sector is key to structure a long-lasting financing strategy.
Cultivar testing has related costs (e.g. facilitation, coordination) that cannot be reduced below a certain threshold, even in the context of frugal on-farm networks where the experimental design and data analysis are optimized in terms of their cost efficiency. On the other hand, participatory cultivar testing creates added value for the different players involved and for the organic food system in general.
Participatory cultivar trials are the joining link between breeding efforts, seed production and real-world organic farming. Organic farmers can directly experience the suitability of the cultivars for their local conditions. On-farm trials are foreseen to increase farmers' trust in the evaluation results' at the field scale, in the context of frugal cultivar testing networks for organic agriculture, which boosts the uptake of locally adapted cultivars and promotes local seed systems. Farmers, as both co-creators and users of the value created by the cultivar trials, are essential components of the financing strategy. Visibility and results from field scale use of their cultivars is a key motivation for breeders and seed producers. Because of this, providing seed and technical assistance for the trials is common interest of breeders and seed producers. The contribution of breeders and seed producers can change according to the different organizational models of organic plant breeding initiatives, but in general, it can be considered as an important element both for covering certain costs and for exploring the value created by the cultivar trials. In the set-up foreseen for the frugal organic cultivar testing networks, the value of the trials is evident also for other actors of the value chain (in terms of quality and integrity of the derived products). This can be used as trigger for a collective effort across the organic food systems and as a basis for an integrated long-term, sustainable financing strategy.

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4 Practical examples

Considering all the constraints at stake and the interconnection among all parameters, project participants can get easily lost. Of course, there is not a miracle recipe to organize a cultivar testing network. The Frugal Innovation Strategy proposed by Abhi Agarwal (www.jugaad-lab.com) can be a useful framework (Table 3).

Frugal strategy canvas	Cultivar testing model
1. What is the real problem that I want to solve? What is my intention?	How to set-up or optimize cultivar testing networks for organic?
2. What are the targets and objectives / non-negotiable constraints?	To be defined by the project manager together with all partners. *Section 3.1 presents examples of objectives.* *Sections 3.2, 3.3 and 3.4 describe the various constraints*
3. How can I encourage internal and external communities to cooperate?	*Section 3.2. on network facilitation explains how to better cooperate.*
4. What can I increase, add or improve above standards?	Not relevant here?
5. Which resources can I leverage?	Webinars in section 2.2 and examples in chapter 4 may be inspiring resources
6. Natural resources, waste, features that need to be removed, reduced or replaced?	Not relevant here?
7. Can the solution be robust, modulable, simple, sustainable?	Examples in chapter 4 present initiatives that strive to cope with their constraints and create alternative models.
8. What are the adjacent revenue streams, leasing models and other innovative value distribution models?	Section 3.5. on the economic models provides some thoughts.

Table 3 *- Frugal strategy canvas (adapted from Abhi Agarwal; www.jugaad-lab.com)*

Get inspired by others

The methodology to be applied depends on one's objectives and constraints. To select the method that fits with a specific situation, a decision tree was presented in the previous section (Fig. 10). To illustrate how these methods can be implemented, concrete examples and outputs are presented hereafter, which can be linked with the decision tree of Figure 10 or described over two dimensions (axes): research team support (x) and type of data (y) (Fig. 12). These five examples rangefrom "in-depth, quantitative data collection -on few pilot farms- with a strong research team support" to "qualitative data collection from a wide base of participation through citizen science and an online tool".

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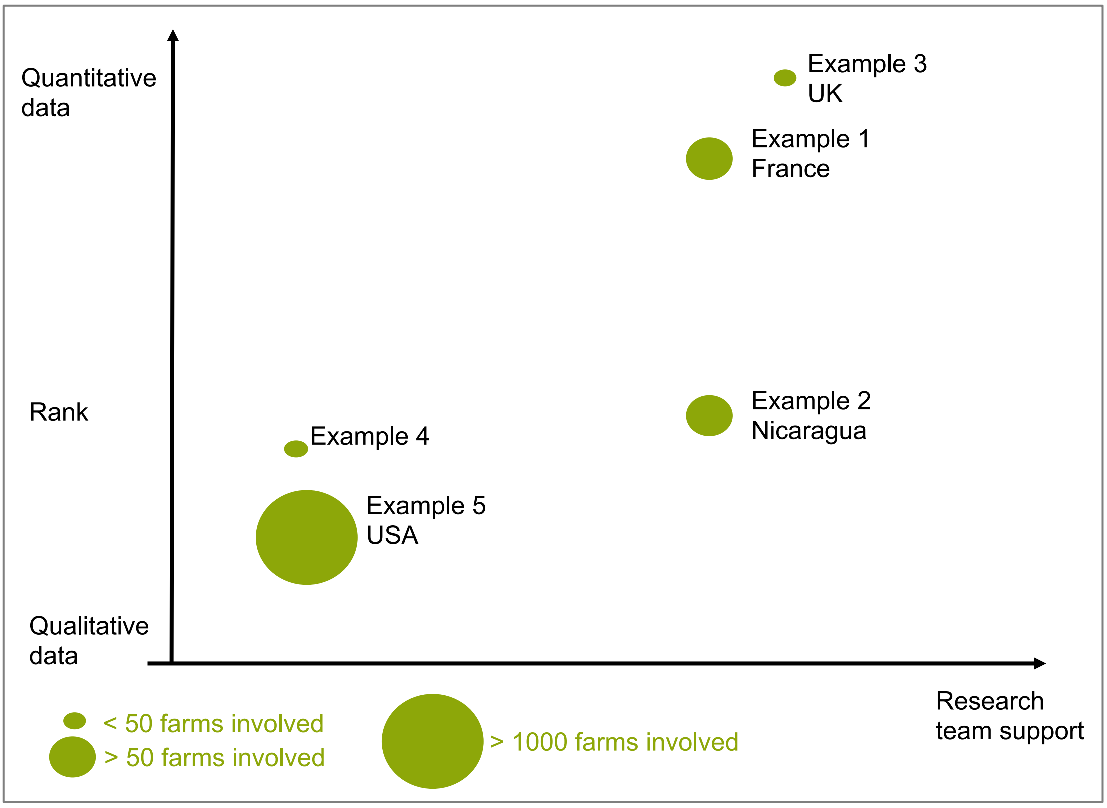

***Figure 12** – The 5 contrasted examples with on-farm trials presented in Chapter 4 and described over two dimensions (axes).*

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4.1 Example 1 - Participatory wheat breeding in France

Objectives
Breed new varieties of bread wheat in a network of farmers in France.

Resources

What do I have ?	What do I not have ?
• a multidisciplinary research team • a national and regional facilitation • a software to manage and analyse data • several farmers willing to evaluate new varieties and take measures • technical staff to measure quantitative data on some farms • lab facilities to receive and measure samples from all farms • funds through project(s) and foundation(s) • possibility to manage small plots	• large amount of seed for each variety except a control • space on farms for the trials

Network facilitation and coordination
National coordination is ensured by the research team and the national farmers' network for the following activities: experimental design, data centralization, organization of national meetings, data analyses, results discussion. Local facilitators ensure coordination with farmers. Several meetings are organised at the regional or national level in order to discuss results and exchange seed.

Experimental design
The experimental design is based on a satellite/regional farm network: all farmers agree on a common control that is sown in each farm of the network and each farmer chooses the varieties he/she wants to sow (landraces, stand-alone or in mixtures, new germplasm coming from crosses or others). The control is replicated at least twice. There are between 5 and 30 varieties per farm and around 50 farms in total. The varieties were chosen mainly with historical and geographical criteria in mind: new varieties resulting from well known crossing parents are tested together with varieties chosen randomly.

Data quality management
Qualitative measures are taken on forms specifically developed for the project, by farmers themselves. Quantitative measures are taken by the research team that visits some farms and receives samples of spikes from each of the varieties from every farm. All data are recorded into the database SHiNeMaS[6].

Economic model
The work is funded through projects and a foundation.

[6] https://sourcesup.renater.fr/projects/shinemas/

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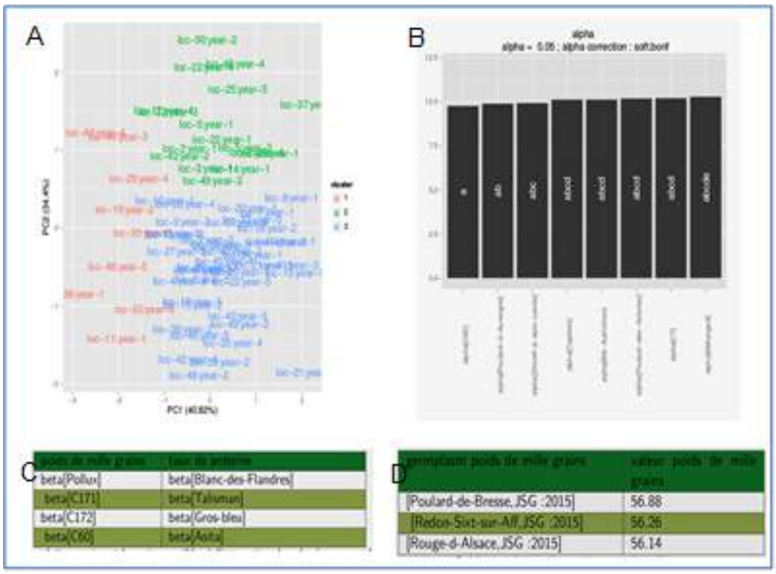
Analysis



The analysis is done with the R package PPBstats[7]. Thanks to the analysis, farmers can get information on the varieties cultivated on their farm (mean comparisons, figure B) and on the network of farms (groups of locations, figure A; varieties with high or low sensitivity to interaction, figure C; prediction of traits for a variety in a given location and a given year, figure D). In addition, every year organoleptic analyses are conducted on a subset of populations from selected regions. Based on this information and thanks to knowledge exchange through meetings, farmers can carry out selection activities based on their objectives.

Positive and negative, frugal and non-frugal aspects for each constraint

Constraints	Positive / Frugal	Negative / Non-frugal
Facilitation	The facilitator is a link between all the farmers outside the meetings: he/she spreads knowledge among farmers.	National coordination by the research team and the national farmers network. Local facilitators allow local coordination.
Design	All farmers must agree on the common control, to avoid that each farmer chooses the variety he/she wants.	At least 25 farms must participate to run the analysis.
	Many varieties can be evaluated	
	The design supports the detection of varieties'response to selection, local adaptation and the choice of varieties mixtures.	
	High number of farms	
Data collection	Interface to manage data available (ShiNeMaS)	Centralised data management that requires specific knowledge
	Qualitative data collected by farmers	Quantitative data collected by the research team
Economic model		Funding dependent on national public projects and foundations
		Dependent on regional projects for local facilitation
Analysis	Free R package available to do the analysis (PPBstats)	Specialised scientific knowledge needed to run analysis
		Analysis possible only on quantitative data

[7]https://priviere.github.io/PPBstats_web_site/

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What's next/ Road map

- Train local facilitators on decentralised data management and analysis
- Update PPBstats and add new analyses
- Organize regional and national meetings to share locally produced results
- Think of an economic model allowing the local organisation to carry out PPB as autonomously as possible

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4.2 Example 2 - Bean varieties in Nicaragua

Objectives
Introduce varieties together with recommendations about them, to help farmers match the best bean variety with their field contexts in Nicaragua.

Resources

What do I have ?	What do I not have ?
• a multidisciplinary research team • a software to manage data and perform the analysis • several farmers willing to evaluate new varieties and take rank measurements • field agents to collect data • funds through projects and foundations • no limitation in the seed for the tests • access to climate data	• space on farm to run trials • quantitative measures • possibility for small plots

Network facilitation and coordination
Facilitation is ensured by the research team. There are three moments of exchange with the farmers: (i) explaining the experiment and distributing the seed, (ii) collecting evaluation data, and (iii) returning the results.
Organized group meetings take place before and after the cropping cycle, but only one or none takes place during the cropping cycle. In the meeting after the cropping cycle, farmers receive information based on statistical analyses of the data. One important motivation for farmers is to have contact with the field agents in order to receive information and training.

Experimental design
Each farmer ranks the performance of three varieties randomly assigned from a larger set of around 10 varieties (tricot trial) and sown with a locally known variety. The trials were conducted on several farms with different seasonality and planting dates. The experiment was carried out on 842 plots during five cropping seasons between 2012 and 2016.

Data quality management
Each farmer ranks the variety for 6-8 traits including agronomic traits, yield, consumption value, market value and the 'overall performance', i.e. whether farmers would plant this variety again. The farmer can report the measurements on paper, communicate these through a phone call or record them on an application for mobile telephones. A digital platform was created to centralize all the data: https://climmob.net. In addition, field agents collected the data through visits or phone calls. Farmers' observations were linked with their geographic coordinates, planting dates and agroclimatic and soil variables.

Economic model
This work was funded by public projects and foundations.

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Analysis

The analysis of ranking was carried out in R (PlackettLuce package)and investigated the influence of seasonal climatic conditions on variety performance. The figure presents an example of the analysis' output, by which two groups of varieties are created based on night temperature. The output gives an idea of farmers' overall appreciation of the tested varieties compared to their local varieties.

In addition, based on climate data, recommendation about varieties with a potential to better perform in a given geographic area are proposed to farmers.

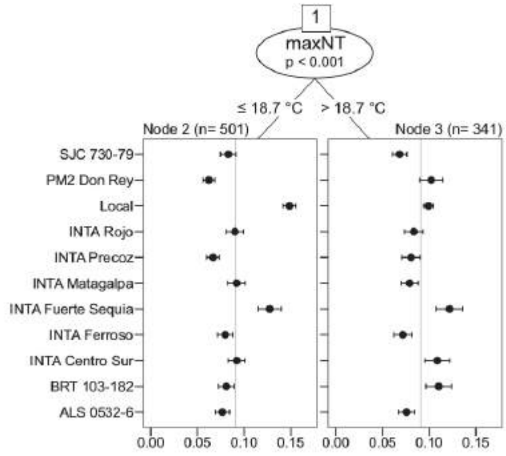

Fig. 2. Plackett–Luce trees of tricot trial data and associated climatic data for common bean in Nicaragua. The horizontal axis of each panel is the probability of winning of varieties. Error bars show quasi-SEs. The gray vertical lines indicate the average probability of winning (1/number of varieties). In this case, the model selected maxNT, the maximum night temperature (degrees Celsius) during the vegetative and flowering periods, as the covariate. Equivalent figures for the trials in Ethiopia and India are shown in *SI Appendix*, Figs. S2 and S3.

Positive and negative, frugal and non-frugal aspects for each constraint

Constraints	Positive / Frugal	Negative / Non-frugal
Facilitation	The facilitator is a link between all farmers outside the meetings: he/she spreads knowledge among farmers.	The research team coordinates the project. Field agents ensure field coordination.
	Farmers can participate individually: and do not need to be organized in collaborative group	
Design	Only 3 plots per farm of a size manageable for farmers	Low number of varieties tested (10 in total)
	High number of farms	Important amount of seed needed for each variety tested
		Farmers do not choose the varieties to be tested
Data collection	Ranking based on a single criteria (which variety is the best, which variety is the worst?)	Accurate climate data require expensive infrastructure: - cost of the material: 25$ to have temperature, 60$ to have temperature and humidity - material may be lost/damaged - effort needed to collect the data
	Farmers measure the data	Field agents collect the data
	Data collection can be done by phone	
Economic model		Dependent on public projects and foundations
Analysis	Free R package available for the analysis (Plackett-Luce)	High scientific knowledge needed to run analyses and manage the interface
	Interface to manage the project exists (https://climmob.net/blog/)	The analysis is reliable if environmental data are available

LIVESEED is funded by the European Union's Horizon 2020 under grant agreement No 727230 and by the Swiss State Secretariat for Education, Research and Innovation (SERI) under contract number 17.00090.

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4.3 Example 3 -Farm-based organic wheat variety testing in the United Kingdom

Objectives

Optimise varietal choice for organic wheat – identify the best set of cultivars for organic farms

Resources

What do I have?	What do I not have?
• a multidisciplinary research team • a software to run the analysis • several farmers willing to evaluate new varieties • technical agents to measure quantitative data on some farms • funds through projects • potentially large amounts of commercial seed for each variety(but subject to availability)	• space on farm to implement formal plot-scale trials

Network facilitation and coordination

Farmers were interviewed on their practices. Each location was visited in June in each year for key measures. At the end of each growing season, a further meeting with farmers was organized to share, discuss and validate the results.

Experimental design

A balanced incomplete block design was adopted the first year and an unbalanced incomplete block design the second year. There were a total of 11 varieties over11 farms. Plots are wide enough to be easily drilled, managed and harvested with farm machinery according to the farm's routine management practices. In each farm, all varieties were drilled on the same day, managed in the same way, and harvested on the same day. Two sets of farms followed different practices for sowing and harrowing. Varieties were selected using information from experimental organic plot variety trials and from farmers' experience.

Data quality management

Soil texture was reported by farmers and crossed with the information in existing soil databases. Temperature data obtained from the stations of the Governmental Meteorological Office and closest to farms. The research team measured key performance variables in June such as heading time, weed infestation and disease incidence. Yield was measured by farmers. Quality was tested by independent laboratories.

Economic model

This work was funded by the LIVESEED project, which also provided seed to the farmers.

Analysis

A mixed model was done using a specific package in R (lmer). Several results were then shared, among which the effect of soil type and spring rainfall on variety performance; the effect of different varieties and environments on grain yield and grain protein content (cf figure); and the impact of different varieties and management on weed abundance.

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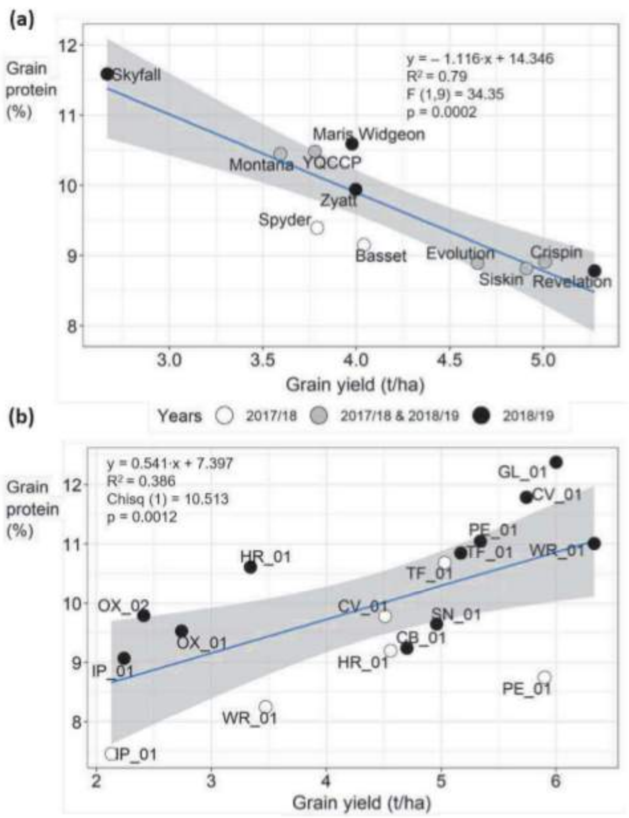

Figure 4. Estimated marginal means (emmeans) of grain yield and grain protein content by variety averaged across year and farm (a) and by farm and year, averaged across variety (b). Trendline and 95% confidence interval of linear model regression of grain protein emmeans as affected by grain yield emmeans, R-squared (R^2), F-value (num. and den. degrees-of-freedom) and p-value of the linear model are shown in chart a. Trendline and 95% confidence interval of linear model regression of grain protein content emmeans as affected by grain yield emmeans, R^2, Chi-square and p-value of likelihood-ratio test against the null model of a linear mixed effect model assuming year as random intercept, and residual variance of the REML-fit model, are shown in chart b.

Positive and negative, frugal and non-frugal aspects for each constraint

Constraints	Positive / Frugal	Negative / Non-frugal
Facilitation	The facilitator is a link between all farmers outside the meetings: he/she spreads knowledge among farmers.	The research team coordinates the project. Field agents ensure field coordination.
Design	Flexible incomplete block design	Only 11 varieties tested
	Farmers follow their field practices	
Data collection	Accurate quantitative variables	Almost all measures taken by the research team
	Farmers measure yield	
Economic model	The varietal strips in each farm are harvested and sold/used. One farm has	Dependent on public project and foundation

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	included the harvest from the trials in his business model based on grains from diverse varieties for home/small-scale milling	
Analysis	R package available to run analysis	Specialised scientific knowledge needed to run the analysis and administrate the interface

What's next/ Road map

The project was frugal on farm but non-frugal at a network management and data collection level. The roadmap can be summarised as follows with the present example as step 1:

1. Years 1 and 2: the LIVESEED proof of concept
2. Years 3 and 4 (in progress): significant expansion of the scope thanks to the LiveWheat project (funded by DEFRA), which deepens the understanding about farming systems – beyond varietal choice, including weed community assessments, integration of climatic and environmental data, feedback into plant breeding.
3. Year 4 and future perspectives: empower farmers/users towards long-term viability based on the principles of frugality; define a decisional framework encompassing varieties, environment and management.

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4.4 Example 4 - Describe and compare several cereal varieties in combining text and quantitative data

The group is formed by 35 gardeners and 15 farmers working on cereals.

Objectives
To maintain cultivated biodiversity, describe and compare several varieties in the network.

Resources

What do I have ?	What do I not have ?
• several farmers and gardeners willing to evaluate varieties and take measures • large amount of seed for some varieties • a collaboration with a researcher	• a multidisciplinary research team • a software to manage data and to run he analysis • technical agents • lab facilities • funds

Network facilitation and coordination
The group is organized into an association. There is no facilitator in the group. One person is responsible of the organization of two meetings a year: one for sowing and one for harvesting. During the first meeting, just before sowing, everybody exchanges seed and agrees on the experimental design, as well as the data management and economic models.

Experimental design
Gardeners manage plots of $1m^2$ and farmers manage plots of minimum $1000m^2$. For volunteers, a common variety is sown. Seed is provided by the group, the common variety is decided based on the amount of seed available. Sowing is done by hand. When mechanical harvesting is not possible, it is done by hand during the “harvest meeting”.

Data quality management
The protocols are defined during the first meeting before sowing. Three types of data are produced:
- ***Text data describing the varieties***: everybody takes general notes/comments on the behaviour of the variety in spring and at harvest. Each person brings a copy of his/her notes to the harvest meeting.
- ***Quantitative data (weight of grain and of straw)***: everybody brings spikes and straw to the “harvest meeting”:the weight of the grain and of the straw are measured and enter into a shared file uploaded to the Internet.

The data produced is as follows:

	Gardeners (35 in total)	Farmers (15 in total)
Texts with variety descriptions	15	10
Quantitative data with weight of grain and weight of straw	10	5

All data are maintained by the group.

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Economic model

All the work is done with limited funds (membership fees of the association) and is based on volunteers. Recently, harvesting machinery was purchased through crowdfunding. The shared data file is stored on the server of a local association that provides free software and tools. The group relies on the help of a researcher for analysing the data produced and participate in its interpretation. The salary of the researcher is paid by the state (permanent position).

Analysis

Text with descriptions of varieties

A workshop is organized during the "harvest meeting" in order to share the observations recorded in the participants' notes during the year. Participants are divided into groups of 5, mixing gardeners and farmers. Group exchanges are then shared in plenary.

Quantitative data about grain weight and straw weight

In total, quantitative traits were measured on15 locations. A hierarchal bayesian model were applied to estimate the genetic, location and sensitivity effects. Since the model works only with a minimum amount of data, no analysis can be done in the first year. From the second year onwards, enough data will be available to run the model. Results are discussed during the "sowing meeting".

Positive and negative, frugal and non-frugal aspects for each constraint

Constraints	Positive / Frugal	Negative / Non-frugal
Facilitation	Auto-organised group. One person is responsible for the organisation of meetings.	Fragile organization if no volunteer does the job
Design	Very flexible	
	All participants agree on the common control, to avoid that each participant chooses the variety they wish.	
Data collection	Carried out at the "harvest meeting".	Complicated organization to avoid mistakes in measures.
Economic model	No funds, only membership fees	
Analysis	Managed by the researcher (on a volunteer basis)who uses dedicated software	If the researcher has no time, no analysis is possible.
	Workshop to discuss text notes is easy to organise.	Workshop to discuss texts are not analysed. Only oral knowledge created and exchanged
		Not enough data to perform a statistical analysis in the first year
		Very few data collected

What's next/ Road map

- Find a way to continue the work of the group in case no researcher is available

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4.5 Example 5 - SeedLinked (USA)

Objectives

Simplify collaboration and amplify results: facilitating a diverse seed system with a collaborative digital platform. Connecting plant growers and their data to help breed, source and harvest the best seed.

Resources:

What do I have?	What Do I not have?
• A large network of growers (>2000) • A digital platform to coordinate trialling, data collection and results sharing • A software • A business model: Marketplace • Funding via business model, grants, investments	• Quantitative data • Advanced protocol for data quality management • A facilitation and coordination team

Network facilitation and coordination

The network facilitation and coordination is ensured by the Seedlinked software itself and by social media. The digital platform allows interactive data visualization, and is connected in real time to the network. A social media platform allows instant exchange of reviews, pictures, comments, questions, resources through the platform.

Experimental design

Participants follow a triadic design, each analysing 3 varieties coming from a larger set. Each participant measures qualitative data, gives a rank, writes text, takes pictures and notes down the dates. There are no quantitative data neither replicated trials.

Data quality management

Data are crowdsourced directly from growers via a mobile app. There are no quality control processes in place yet. A trade-off must be found between quantity and quality as well as between reliability and accuracy.

Economic model

The economic model clearly requires identifying where the added value is. The business models focus on four items:

- SaaS: Subscription service to use of collaborative trialing software
- Transaction fee on seed marketed through the platform
- Premium membership
- Procurement

Finding the best variety for a given set of conditions and market using collective data is the highest value added identified. Transaction fees and/or a click through rate can be collected via a marketplace/ search engine. That money finances the platform. A royalty that will go toward financing breeding project can also be captured.

A procurement feature on top of the platform where demand and offer are matched could be added (like Indigoag.com and FBN.com did in the USA).

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Analysis
The rank analyses coming from the triadic trials are done with the R package PlackettLuce. Descriptive analysis are also done. More advanced proximity models are planned in the future.

Positive and negative, frugal and non-frugal aspects for each constraint

Constraints	Positive / Frugal	Negative / Non-frugal
Facilitation	Decentralised and self-run	Maybe less peer to peer
	Higher number of participations thanks to lower barriers to entry.	Loss of 15% participants due to the need to use technology, but more than double participation
Design	Simple design	Lower number of varieties
	Very high number of locations	Non quantitative
Data collection	Scoring and ranking via mobile apps. Instant data sharing.	Non replicated design yet
Economic model	Fee % from marketplace & SaaS	Need customers, for profit managed
Analysis	Connected data. Search engine. USDA Hardiness zone breakdown, traits, maturity, pictures, simple growing conditions filters…	Limited internal analysis capacity

What next/ Road map

- Increase engagement via social media and improved search engine features
- Launch the marketplace and generate revenue to self-fund the project
- Improve the prescriptive model behind search engine
- Introduce quantitative and environmental data layering
- Include trait ontology for more granular crops
- Develop analytical tools within the platform
- Internationalization: include more languages and mapping (e.g. EU)
- Pilot business model in the EU and Africa

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5 Crop specific protocols

The following crop specific protocols were prepared under the coordination of ÖMKi (Judit Fehér) and with the contributions of other project partners as authors and reviewers (see Annex).

1. **Cereal (winter and spring wheat, winter and spring barley) protocol** – *author: Judit Fehér (ÖMKi) and Ambrogio Constanzo (ORC), reviewers: Péter Mikó (ATK) and Szilvia Bencze (ÖMKi)*
2. **Faba bean protocol** – *author: Tove Mariegaard Pedersen (SEGES), reviewer: Judit Fehér (ÖMKi)*
3. **Cabbage (kohlrabi, broccoli and cauliflower) protocols** – *authors: Mathieu Conseil (ITAB) and Noemi Uehlinger (Sativa), reviewer: Abco de Buck (LBI)*
4. **Carrot protocol** – *author: Mathieu Conseil (ITAB), reviewer: Abco de Buck (LBI)*
5. **Potato protocol** – *author: Ilze Skrabule (AREI), reviewers: Mathieu Conseil (ITAB), Orsolya Papp and Judit Fehér (ÖMKi)*
6. **Tomato protocol** – *authors: Matteo Petitti (RSR) and Adrian Rodriguez Burruezo (UPV) reviewers: Orsolya Papp and Judit Fehér (ÖMKi)*
7. **Apple protocol** – *author: Kostas Koutis (Aegilops), Niklaus Bolliger (Poma Culta) and François Warlop (GRAB) reviewer: Judit Fehér (ÖMKi)*

At the beginning of the project, the above listed crop species were selected as targets for the investigation of cultivar testing models under organic conditions at on farm/field scale as well as in some cases at on-station/plot scale. These are strategic crops, being among the main arable and vegetable species grown in Europe and/or species where frequent derogations for the use of untreated conventional seeds in organic farming are requested.

Beyond the collection of trial data, partners assessed the organisational model, the experimental design, the statistical analyses, the data management options and the costs and funding schemes of these trials.

The crop specific protocols are the result of this integrated set of information and are based on the authors' experience in conducting organic and/or low input trials.

How to use these protocols

As described in Chapter 3, experimental design and data analysis need to be developed in combination with standard methods and adapted to the objectives and constraints of each network. As a consequence, the protocols proposed here are not ready to use. Chapters 3 and 4 provide methods and guidelines on how to proceed and which steps to consider when designing your own trials.

In order to find the best suited **experimental design** to your objectives, we suggest to consult Chapter 3.3. However what follows is a compilation of some general guidelines from the authors of the protocols, which can be applied to any crop species.

In case of farm-scale trials, considering individual farms as blocks, the use of **incomplete block designs** is suggested, ensuring optimal balance between:

- as many varieties as possible on-farm to maximise direct comparison

- as few varieties as possible on-farm to make it easier for the farmer.

A key aspect of this design is that every "contrast" (i.e. pair of varieties occurring in the same farm), should appear at least once in the group of farms involved. An on-farm network can also rely on a single or few plot trials, therefore reducing the costs and improving the commitment (participatory approach). An additional option which increases the frugality of the system is doing a complete randomization considering 3-4 years data, i.e. a sort of vertical randomization. Plots of other cooperating farms (or of participants and research centres in other countries in the case of international testing), picked up in different environments, can be considered as spatial randomization.

The protocols offered in this document should be considered as sources of inspiration, supporting the choice of the most relevant datasets to match your experiment and financial resources. Data marked as "considered important for the organic sector" come from the experiences of LIVESEED project partners in running participatory cultivar trials under organic management for many years. However it is important to note that no variable is *a priori* mandatory, but each chosen one should be linked to your objectives and coherent with the methodology used (see Chapter 3). On the other hand, some variables cannot be evaluated in frugal trials, they can be added to the protocol depending upon the context, the availability of funds, in-kind contributions and the type of partners participating in the effort.

- In order to develop your own protocols, here are some useful resources:
- *Handbook: Cereal variety Testing in Organic and Low Input Agriculture*. Ed. Dingena Donner and Aart Osman, COST860 – SUSVAR (2006)
- *The Grower's Guide to Conducting On-farm Variety Trials.* Colley, M., Dawson, J., Zystro, J., Healy, K., Myers, J., Behar H, and Becker, K., Organic Seed Alliance (2018) https://seedalliance.org/wp-content/uploads/2018/03/Growers-guide-on-farm-variety-trials_FINAL_Digital.pdf
- *Comparaison de variétés de céréales à paille en AB – Protocole et modes opératoires*. Sicard H., Guilhou R., Fontaine L., ITAB (2019) only available in French http://itab.asso.fr/downloads/fiches-ble/varietes-tri-epe-bio_synthese-2019_9oct.pdf
- *Organic Farm Knowledge Platform/ Plant breedin and variety trials* https://organic-farmknowledge.org/discussion/theme/237

For an organoleptic quality assessment, please consult the following booklet:

- *Tools to integrate organoleptic quality criteria into breeding programs.* C. Vindras et al., ITAB. Diversifood technical booklets. (2018) https://orgprints.org/38095/1/Tasting%20guide-DIVERSIFOOD_2018-VF.pdf

The goal of these guidelines is to walk researchers, breeders, farmers and other stakeholders, through the process of planning, implementing and evaluating frugal participatory cultivar trials. This may be a helpful tool to support them in developing optimised protocols tailored to their diverse agroecological systems.

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6 Perspectives and recommendations for a future European model

6.1 The potential of ICT and citizen science approaches in setting up frugal cultivar testing infrastructure: lessons learned from the SeedLinked initiative

After laying out the multiple constraints which limit European seed collaborative initiatives to scale out and expand, the LIVESEED Workshops and Webinars identified potential solutions that could drastically improve and unlock the potential of frugal variety testing models, particularly by harnessing the potential of ICT technologies in easing large-scale collaborative data collection, analysis and use (van de Gevel et al. 2020). The initiative explored in more detail was the crowdsourcing model presented by Dr Jacob Van Etten (Alliance Bioversity-CIAT) and Dr Nicolas Enjalbert (SeedLinked). Both demonstrated that simple crowdsourced models are highly accurate, drive engagement and adoption, can be scaled to very large growers' networks and are very cost effective.

In our European context it is time to be bold and ask ourselves: What if we could:

- Simplify collaboration to involve more people via novel crowdsourcing models?
- Amplify results and their impact using cloud computing and mobile devices to favour wider engagement?
- Keep data highly relevant and accessible by building proper database architectures and ensuring full connectivity
- Connect European farmers and their data through a collaborative digital platform which adds exponential value to the whole supply chain?

This hypothesis emerged and was discussed during the LIVESEED Workshops and Webinars presented in chapter 2. An overall scheme for an ideal model, illustrated in Figure 13, was drafted with inputs from Nicolas Enjalbert (SeedLinked, CEO): it aims at integrating and solving some of the constraints identified in chapter 3. It was designed based on the frugality principles and on the SeedLinked[1] experience, with the aim to overcome barriers to collaboration. It is a promising frame to be further developed and adapted to the European context in future projects. Table 4 describes the pros and cons of this proposal.

The basic concepts of the model were presented at the LIVESEED final conference, in a Workshop "New models of cultivar testing for organic agriculture" held online the 24th of November 2020. In a short poll proposed to participants, they unanimously considered this proposal as a promising opportunity.

A collaborative digital platform -combining cloud computing, data architecture, data science and data visualisation-, with data directly crowdsourced by farmers via a mobile app, would allow instant result sharing. For such a platform to be successful, the user experience (UX) and user interface (UI) become essential. This implies the need to implement a strong UX/UI process before setting up the experimental designs (simplified, such as Tricot[2] or rating), the trait scoring system and the access protocols. The UX/UI process requires bringing highly talented designers and growers together to create a digital ecosystem that can guide the users and make them confident and empowered.

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Once established and validated, the platform can make collaborations more efficient, and encourage participation of a more diverse set of actors, generating direct added value to all users. This is when virality and network effect build up creating the virtuous cycle needed for generating exponential value.

More participants, which also means more locations and a broader diversity of situations, increase the validity of the results. Funding is needed to develop, implement and deploy the digital system and trigger the network effect. Instead of starting a new digital system from scratch, existing ones, such as SeedLinked, could be adapted (according to terms to be defined/discussed) to the European context, in terms of languages, GPS data, regulations and other specific aspects. Proper database architecture and context data need to be crowdsourced to avoid the results being too generic.

For such system to work and create full engagement, it needs to be accessible, decentralised, collaborative, democratic, and able to accommodate for a multi-actor and diverse approach, generating high value for everyone. In our case, beneficiaries would be at first farmers**,** who could easily find the cultivars best suited to their needs and context, but also seed suppliers, breeders, researchers and extension services, who could better characterize cultivars in a diversity of contexts and/or select for local adaptation.

To push the boundary even further, social media features can be built in the platform creating more virtual peer to peer exchange and engagement via some gamification. However, even with a model based on the combination of decentralised on-farm trials, citizen science and a collaborative digital platform in person meetings with local network members will still play a very important role. Such meetings will benefit from the wealth of pre-existing virtual exchanges through the platform and social media, and can be organised to focus on specific issues such as proposing new cultivars to test or performing a collective organoleptic quality assessment (possible with SeedLinked too).

Finally, data ownership and governance are crucial issues to be addressed with stakeholders during the system development and should be at least based on the EU regulation “General Data Protection Regulation” (GDPR). As starting point, the “EU Code of conduct on agricultural data sharing by contractual agreement”[3] may be an useful resource. The business model is another fundamental pillar to be further addressed. Because the described innovation amplifies the co-created value, it offers multiple options of high value proposition-based business models such as “Subscription service to platform” from breeder or trialing organization, or such as premium membership to growers. A decentralised, diverse, collaborative, sustainable and resilient seed system then becomes a closer reality.

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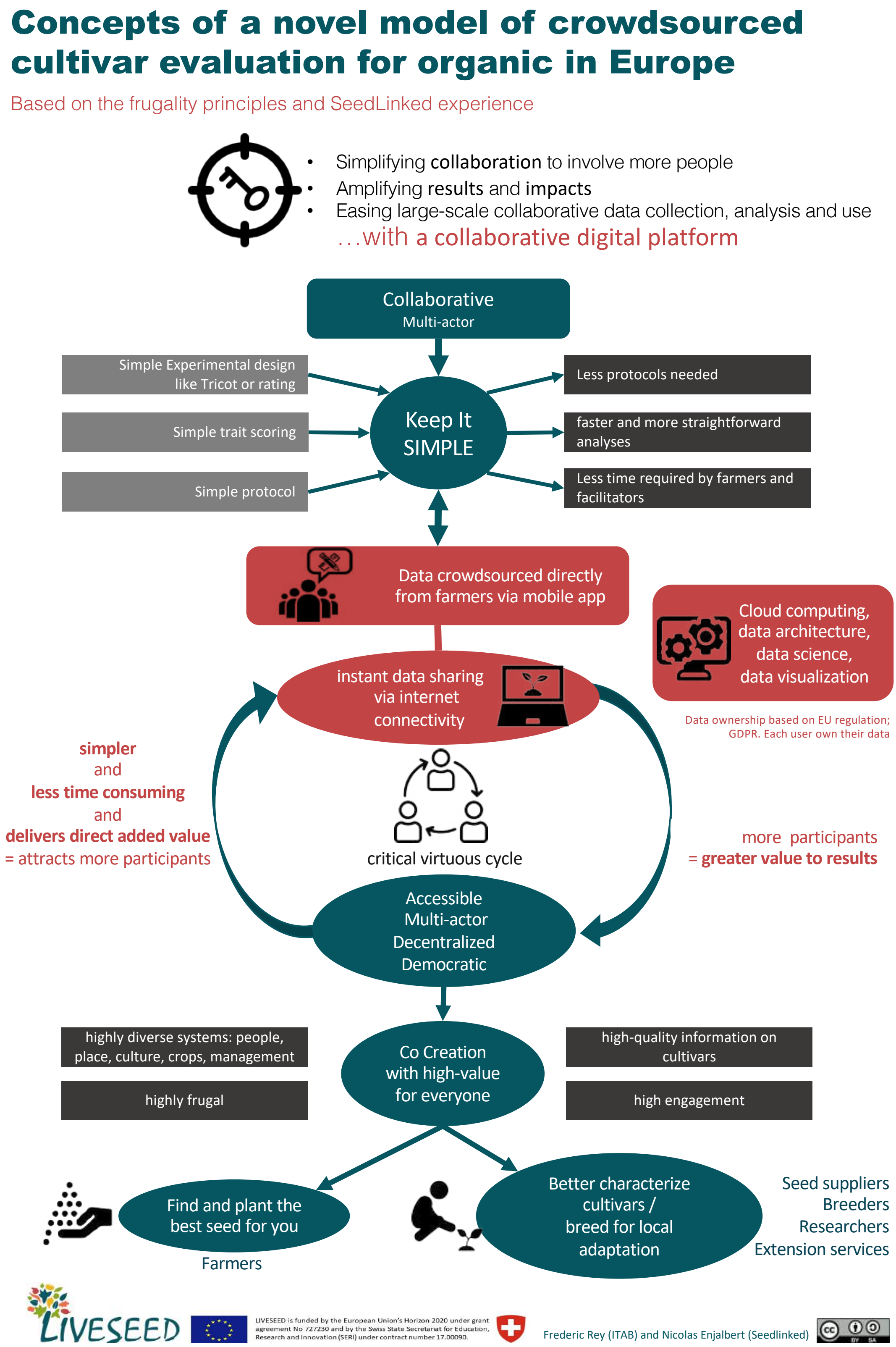

Figure 13 – Concepts of a novel model of crowdsourced cultivar evaluation for organic in Europe based on ICT technologies.

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Pros	Cons
• Easier collaborative testing: boosts adoption and participation (+100% in the USA with SeedLinked) • Less logistic investment for trials • Real time result sharing • Reduce cultivar trialing costs (by 10x in the USA) • Better on-farm prediction • Farmers can make more informed choices about locally adapted cultivars / find seed for their needs • Breeders can better breed for locally adapted cultivars • Collective evaluation can be immediately connected, across places, time and people • More power is awarded to independent seed stakeholders by giving them testing opportunities at a lower cost, and access to market boosted by data • Seed transparency • Increased use of crop diversity • Reliable data on cultivar characterisation • Boost adoption of new varieties • Better synchronisation between demand and supply lowering the market risks of organic seed production	• It is a digital tool and cannot replace in person interactions • Data are related to a given context, i.e. caution is needed when generalising the results • Technology dependent • Data ownership & ethics • Business model required for long-term resilience • How to accommodate the diversity of crops, people, cultures into a single platform? • Not 100% inclusive: although it can exponentially increase the users base, an estimated 15% will not use it, • Some stakeholders may not wish to share their data but however use the tool (a solution could be to provide allow them access with a specific fee and create anonymised data) • A digital solution that suits a diversity of actors and contexts (more data = more robust), versus a diversity of digital tools from different approaches. • The carbon footprint impact of ICT tools to be considered

Table 4 *- The pros and cons of a new cultivar testing model, based on a collaborative digital platform*

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6.2 Conclusion and recommendations

Based on the outcomes of LIVESEED workshops and webinars described in chapter 2, which brought together researchers from institutes of several European countries, the concepts and properties of “new models of cultivar testing for organic agriculture” were identified and described.

These activities led on the one hand, to propose solutions (see Chapter 3) to meet the objective of “how to set up and/or optimize cultivar testing networks for organic farming”. A strategy based on objectives and constraints was developed, and five inspiring examples were provided, to support the development of tailor-made solutions. For many constraints, there are statistical methods that can generate robust and useful decision-making data. Several scientifically validated experimental designs were proposed based on the types of data and specific constraints, for instance the number of cultivars to be tested, the number of farms involved and if replications are needed.

In parallel, the basic concepts for a future European model of cultivar testing were laid out, based on a collaborative digital platform. Even if this solution seems highly promising and has so far received positive feedback, further significant developments are needed before making it available. Several partners within and outside of LIVESEED already announced their willingness to continue in a future (EU?) project together in order to fully respond to this challenge.

Cultivar evaluation can have an outstanding potential in enabling the success of organic farming and of the agroecological transition. **However we highlighted that current infrastructures are fit for purpose to a limited extent, and that new models need to be designed based on a radical innovation pathway.** To this end, we recommend the following course of action:

- The success of organic breeding will be the result of a **transition**, and **cultivar testing is the pivotal mechanism that can unlock relevant technical and societal innovations**. “Breeding for organic” and “organic breeding” can only be successful as far as an appropriate cultivar testing infrastructure is in place, allowing the necessary information flow to farmers and enabling them to plant adapted crops to their target environments.
- The volume of information needed for a cultivar testing infrastructure relevant to organic farming is even higher than in conventional farming, yet the organic sector is still too small to support its costs. This calls for alternative, **radical innovation** approaches to respond to the challenge.
- The concept of **frugality** is key to develop a relevant and cost-effective infrastructure through a mobilisation and redirection of existing resources.
- **Participatory approaches** are not only ethically preferable, but essential to cover the wide range of needs and environmental conditions of organic farming, as well as to mobilise resources in a frugal framework. In fact, unlike official, centralised approaches, we recommend that an effective cultivar testing infrastructure for organic farming is shaped as a decentralised **collaborative network**.
- **Coordination and facilitation** of a collaborative network are fundamental areas of development that require appropriate skills and methods of participatory research and call for a radically new attitude by **scientific/technical actors: from “owners” of knowledge to “catalysers” of empowerment** of multi-actor networks so that these can generate their own knowledge.
- **Alternative experimental designs and data analysis protocols** need to be implemented and adapted to the constraints of each network. With these appropriate solutions, evaluation on farms or in less controlled conditions than those of experimental stations are **not a limit to the**

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robustness and reliability of the results obtained, but instead can even act as a stimulus to creatively adapt existing validated statistical approaches.

- **Data management** needs to be open to a wide range of data types, from quantitative, continuous variables to purely qualitative variables, including quantitative adaptations such as rankings or ratings. This is critical to make **data collection more accessible to a wider range of actors as well as to generate useful data on a greater set of aspects.**
- **Economic models** need to be chosen through exploring or combining different approaches, from public support, to subscription-based or supply-chain cost recovery models. The final model should be developed around and integrated into broader breeding programme financing strategies. In this respect, **alternatives to the royalty-based breeding business models** can be developed for organic cultivar testing, given their inappropriateness to the need to significantly diversify the pool of varieties for organic farming.
- **Integration of ICT technologies** can be a lever to facilitate frugal and highly inclusive and representative cultivar testing infrastructures, as proven by existing initiatives that will need to be further explored and potentially adapted to the European context.

Last but not least, developing an effective cultivar testing infrastructure can reinforce the role of organic farming in being pivotal for a broader transition towards agroecological food and farming systems. Organic cultivar testing models must therefore be seen as a highly strategic objective the societal impact of which can, in the long run, be critical for the whole European agricultural sector.

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Annex - Crop specific protocols

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1. Cereal protocol

Stage of trial design	Plot-scale	Field-scale	Comments
Goal setting	For low-cost trials prioritize a participatory approach - Fulfil basic scientific requirements *For further information see Chapter 3.1*		
Trial scale	Pros: • **Optimal trait assessment** • **Direct comparison** across large number of varieties. Cons: • **Performance might be impaired** by the plot-scale and difficult to translate to field-scale • **Treatments are not fully independent** as e.g. plots need harvesting at the same time • **Cost** might be high	Pros: • Direct varietal comparison in **real-world situations.** • Embedded into farm routine • Might unveil different management systems and their impact on varietal performance Cons: • **Limited number of experimental units per farm** • Need relatively **large quantity of seeds** • Might be able to test a **limited number of varieties**	It is suggested that integration between a limited number of plot-scale trials and a network of field-scale trials can be the optimal arrangement
Experimental design	*For further information see Chapter 3.3*		
Experimental sites	• Trial sites should be in the main growing areas of the crop and possibly cover the main pedoclimatic zones of the country • Choose certified organic trial fields - usually farmers' field • The field of the trial should be as homogeneous as possible; same pre-crop, beware of the field edges, where machinery turns thus compacting the soil	• Identify a network of farmers willing to drill and harvest separate strips of different varieties in their commercial field. • The field should ideally be as homogeneous as possible. • Generate consent forms for the participating farmers as part of a data management plan. • Mark the trial plots in the field.	

	• The field should have a relatively low level of weeds – especially rooted weeds, otherwise variety differences will be smeared	• The field should have a relatively low level of weeds – especially rooted weeds, otherwise variety differences will be smeared	
Examples of site metadata *(should be adjusted according to your objectives and constraints)*	• Soil analyses (texture, N, P, K, other nutrients, pH, soil organic matter). • Pre-crop and cropping history for the last few years. • Climate data – possibly have a weather station on site.	• Identify soil type (texture, pH, soil organic matter, drainage) • Interview with the farmers to ascertain field cropping history, including organic/inorganic fertilisation along the rotation, main tillage operations. • Access soil analysis that the farmer might have performed and complement with new soil analysis if needed. • Agree with farmers to share a log of management operation on the experimental field. • If no own weather station available, identify closest climate data sources and agree about access to data.	
Agree about the assessment protocol *(see soil and crop evaluation protocol below)*	• Focus on varietal traits especially phenology, disease progression	• Identify a set of essential, standard metrics across the different sites • Focus on overall performance, weed community, actual yield and quality	If plot-field-scale are integrated, assessment on specific traits can be intensified at the plot trial and kept at a minimum essential on the farm scale
Selection of varieties for testing	• Two or three standard varieties in each tested maturity group (early/late) should be used at all sites; standard varieties should include the most popular varieties in organic or low input farming • The number of varieties should be optimized to keep costs and labour on a feasible level. • Choose an appropriate variety for trial border	• Identify one variety as common control across all farms. • Identify a reasonable number of varieties relevant to current crop context, including most popular varieties as well as potential new varieties.	If plot-field scale are integrated, the plot trial can serve as a platform to test larger number of varieties that can subsequently be included in the field-scale

			network (which may not be able to test them all)
Seed quality and procurement	• Check germination rate and treat the seeds in case it's necessary (e.g. hot water treatment (*Microdochium nivale*, *Fusarium* spp.) vinegar treatment (*Tilletia caries*))	Use commercial seed. Act in advance to purchase/procure a sufficient quantity of organic and/or untreated seeds for each variety • Quantity might be challenging because too high to enable use of trial seed and too low to be purchased as commercial seed. • Cooperate with seed merchants and avoid arranging seed purchase in the main seed season as delays might occur. • Assist farmers with derogations in case conventional untreated seed needs to be used. • Identify whether any farmer uses farm-saved seed.	
Generate field plans	See experimental design.	Varieties should be drilled as strips wide enough to be harvested separately with farm machinery. At least one variety should be replicated at least twice in each farm.	
Sowing density	Sowing density (g/m2) =[desired density (plant/m2)] × [100 / % germination] × [thousand grain weight/1000]	Be prepared to assist farmers in drilling based on seeds/m^2 instead of kg/ha, therefore adjusting seed rate by grain weight. If not possible, record grain weight and estimate effective sowing density.	
Soil preparation	Small plot drillers usually need better soil than a general sowing machine	Soil preparation must follow farmer common practice and must be recorded.	
Drilling	Record drilling date and climate conditions before and after.	Record drilling date and climate conditions before and after.	

Validation / experiment metadata	After drilling and emergence check if varieties were drilled correctly.	• Visit farms to ascertain that the trial is fit for purpose and that crop establishment is adequate. • Check that varieties were drilled in the agreed positions and/or be ready to correct experimental designs.	
Harvest	Harvest performed with trial equipment.	Make sure yield recording can be done as accurately as possible and be ready to provide assistance to farmers during harvest. Every farmer might have a different yield-measuring system.	
Post-harvest	Collect grain samples for further analyses.	Collect grain samples off-combine to be sieved to obtain admixture values.	
Statistical analysis	*For further information see Chapter 3.3*		

Soil and crop evaluation

Type of data	Variables measured	Measurement/observation scale	Importance	Growth stage
Agro-climatic variables	Soil type and texture		Considered important for the organic sector	
	Soil N, P, K, Mg and pH		Recommended	
	Soil Organic Matter		Recommended	
	Climatic variables (min – max – average temperature and precipitation, etc.). *It is very important to understand what the most relevant metrics are, and what data is needed: daily, weekly, monthly?*		Recommended	
	Cropping system history (previous crop, nutrient/manure application, soil tillage, weed and disease control if applied, etc.)		Considered important for the organic sector	
Crop growth and development	Date of emergence	Date	Recommended	
	Crop emergence and establishment	Plants/m^2; percentage; score	Considered important for the organic sector	1 week after emergence (2-leaf stage)
	Crop seedling vigour	Score; plant height; shoot and root length of germinating seeds (lab)	Recommended	At 2-leaf stage or separately in lab
	Crop ground cover	Percentage or 1 to 9 scale	Considered important for the organic sector	At tillering stage; stem extension stage; booting stage
	Tillering capacity	Number of shoots per plant	Recommended	At the beginning and end of stem elongation
	Inclination of flag leaf	1 to 9 scale	Recommended	At flowering

	Growth cycle length (heading date) (e.g. early/medium/late variety)	The date when 50% of the population is heading	Obligatory	At heading time
	Weed coverage	Percentage or 1 to 9 scale	Obligatory	At heading period and end of stem elongation
	Weed community	different weed species are important in understanding the weed pressure	Recommended	onset of stem extension and in correspondence of flowering / early grain filling
	Overall performance against diseases		Obligatory	From heading till early maturation
	Diseases (leaf and spike pathogens, seed-borne diseases, etc.)	Disease incidence and disease severity – use of standard scales	Recommended	In case of symptoms
	Pests		Recommended	In case of occurrence/symptoms
	Biomass of crop		Optional	Heading and/or full maturation
	Biomass of weeds		Optional	During growth cycle
	Plant height	In cm (from ground to the top, without the awns)	Considered important for the organic sector	After final plant height is reached
	Lodging	Percentage of the lodging plants + lodging angle on a 1 to 5 scale or other relevant scale	Considered important for the organic sector	Before harvest
	Date of maturation	Date	Recommended	
	Date of harvest	Date	Considered important for the organic sector	
Crop performance	Yield per unit area (min. 3×1 m^2 sample plots)	kg/m^2; t/ha	Considered important for the organic sector (if total plot yields can be determined)	
	Yield components (e.g. number of ears/m^2, size of ears, seed moisture content, etc.)		Recommended	can be done between flowering and harvest
	Thousand-kernel weight	g	Recommended	

Quality of products from the trials	Laboratory analyses of basic quality parameters (e.g. protein and gluten contents and test weight in cereals)		Considered important for the organic sector	
	Post-harvest quality		Optional	
	Processing quality (e.g. actual bread-making)		Recommended	
	Nutritional quality		Optional	
	Organoleptic quality *For more information:* https://orgprints.org/38095/ VINDRAS, Camille; Sinoir, N.; Coulombel, A.; Taupier-Létage, Bruno and REY, Frederic., ITAB. Diversifood technical booklets. (2018)		Optional	

2. Faba bean protocol

Stage of trial design	Plot-scale	Field-scale/large plots	Comments
Goal setting *For further information see Chapter 3.1*	For low-cost trials prioritize a participatory approach - Fulfil basic scientific requirements		
Trial scale	Pros: • **Optimal trait assessment** • **Direct comparison** across large number of varieties. Cons: • **Performance might be impaired** by the plot-scale and difficult to translate to field-scale • **Treatments are not fully independent** as e.g. plots need harvesting at the same time • **Cost** might be high	Pros: • Direct varietal comparison in **real-world situations.** • Embedded into farm routine • Might unveil different management systems and their impact on varietal performance Cons: • **Limited number of experimental units per farm** • Need relatively **large quantity of seeds** • Might be able to test a **limited number of varieties**	It is suggested that integration between a limited number of plot-scale trials and a network of field-scale trials can be the optimal arrangement
Experimental design	*For further information see Chapter 3.3*		
Experimental sites	• Trial sites should be in the main growing areas of the crop and possibly cover the main pedoclimatic zones of the country • Choose certified organic trial fields - usually farmers' field • The field of the trial should be as homogeneous as possible; same pre-crop, beware of the field edges, where machinery turns thus compacting the soil	• Identify a network of farmers willing to drill and harvest separate strips of different varieties in their commercial field. • The field should ideally be as homogeneous as possible. • Generate consent forms for the participating farmers as part of a data management plan. • Mark the trial plots in the field.	

	• The field should have a relatively low level of weeds – especially rooted weeds, otherwise variety differences will be smeared • No faba bean or pea cultivation for the last five years, and no legumes as pre-crops • GPS coordinates. • Moist soil or irrigation possibility • Fence may be necessary	• The field should have a relatively low level of weeds – especially rooted weeds, otherwise variety differences will be smeared • No faba bean or pea cultivation for the last five years, and no legumes as pre-crops • Moist soil or irrigation possibility	
Examples of site metadata *(should be adjusted according to your objectives and constraints)*	• Soil analyses (texture, N, P, K, other nutrients, pH, soil organic matter). • Pre-crop and cropping history for the last few years. • Identify source of climate data – possibly have a weather station on site.	• Identify soil type (texture, pH, soil organic matter, drainage) • Interview with the farmers to ascertain field cropping history, including organic/inorganic fertilisation along the rotation, main tillage operations. • Access soil analysis that the farmer might have performed and complement with new soil analysis if needed. • Agree with farmers to share a log of management operation on the experimental field. • If no own weather station available, identify closest climate data sources and agree about access to data.	
Agree about the assessment protocol *(see soil and crop evaluation protocol below)*	• Focus on varietal traits especially phenology, disease progression, pest attacks	• Identify a set of essential, standard metrics across the different sites • Focus on overall performance, weeds, yield and quality	If plot-field-scale are integrated, assessment on specific traits can be intensified at the plot trial and kept at a minimum essential on the farm scale
Selection of varieties for testing	• One or two standard varieties in each tested maturity group (early/late) should be used at all sites; standard varieties should include the	• Identify one variety as common control across all farms.	If plot-field scale are integrated, the plot trial can serve as a platform to test

	most popular varieties in organic or low input farming • The number of varieties should be optimized to keep costs and labour on a feasible level. • Choose an appropriate variety for trial border	• Identify a reasonable number of varieties relevant to current crop context, including most popular varieties as well as potential new varieties.	larger number of varieties that can subsequently be included in the field-scale network (which may not be able to test them all)
Seed quality and procurement	• Check germination rate, purchase a seed health test in case of farm saved seeds, and use only healthy seeds (infection level must be within recommended limits for diseases) and pay attention to seed damage caused by bruchid beetles. Unhealthy seeds can hamper trial results.	Use commercial seed. Act in advance to purchase/procure a sufficient quantity of organic and/or untreated seeds for each variety • Quantity might be challenging because too high to enable use of trial seed and too low to be purchased as commercial seed. • Cooperate with seed merchants and avoid arranging seed purchase in the main seed season as delays might occur. • Assist farmers with derogations in case conventional untreated seed needs to be used. • Identify whether any farmer uses farm-saved seed.	
Generate field plans	See experimental design.	Varieties should be drilled as strips wide enough to be harvested separately with farm machinery. At least one variety should be replicated at least twice in each farm.	
Sowing density	Sowing density (g/m^2) =[desired density (plant/m^2)] × [100/% germination] × [thousand grain weight/1000]	Be prepared to assist farmers in drilling based on seeds/m^2 instead of kg/ha, therefore adjusting seed rate by grain weight. If not possible, record grain weight and estimate effective sowing density.	
Soil preparation	Small plot drillers usually need better soil than a general sowing machine	Soil preparation must follow farmer common practice and must be recorded.	

Drilling	• Record drilling date and climate conditions before and after. • Mark the first plot of the trial.	Record drilling date and climate conditions before and after.	
Validation/experiment metadata	After drilling and emergence check if varieties were drilled correctly.	• Visit farms to ascertain that the trial is fit for purpose and that crop establishment is adequate. • Check that varieties were drilled in the agreed positions and/or be ready to correct experimental designs.	
Harvest	Harvest performed with trial equipment.	Make sure yield recording can be done as accurately as possible and be ready to provide assistance to farmers during harvest. Every farmer might have a different yield-measuring system.	
Post-harvest	Collect grain samples for further analyses.	Collect grain samples off-combine to be sieved to obtain admixture values.	
Statistical analysis	*For further information see Chapter 3.3*		

Soil and crop evaluation

Type of data	Variables measured	Measurement/observation scale	Importance	Growth stage
Agro-climatic variables	Soil type and texture		Considered important for the organic sector	
	Soil N, P, K, Mg and pH		Recommended	
	Soil Organic Matter		Recommended	
	Climatic variables (min – max – average temperature and precipitation, etc.). *It is very important to understand what the most relevant metrics are, and what data is needed: daily, weekly, monthly?*		Recommended	
	Cropping system history (previous crop, nutrient/manure application, soil tillage, weed and disease control if applied, etc.)		Considered important for the organic sector	
Crop growth and development	Sowing depth	cm	Recommended	BBCH 0 (at drilling)
	Date of emergence	Date	Recommended	BBCH 09
	Crop emergence and establishment	Plants/m^2; percentage; score	Considered important for the organic sector	BBCH 32 (two visibly extended internodes)
	Growth stage	Example how to extend the BBCH scale to assess growth stage: – 50: No flower buds visible – 51: Flower buds in lowest wreath – 52: Flower buds in two lowest wreaths – 53: Flower buds in three lowest wreaths – 60: Beginning of flowering in lowest wreath – 61: 10% of flowers open Alternative: Date of beginning of flowering (will need several visits as compared to the above method)	Recommended	BBCH 51-61 (from first flower buds visible outside leaves until flowers open on first raceme)

	Weed coverage	1 to 9 scale or other relevant scale or percentage	Considered important for the organic sector	BBCH 69 and stage 89 (end of flowering and before harvest)
	Weed community		Recommended	at various phenophases
	Overall performance against diseases		Considered important for the organic sector	BBCH 51-75 (first flower buds visible to 50% bellows in full size
	Diseases (leaf and spike pathogens, seed-borne diseases, etc.) Chocolate spot disease (*Botrytis fabae*), rust leaf spot (*Ascochyta fabea*), vetch mold (*Peronospora viciae*)	Disease incidence and disease severity – use of standard scales	Recommended	In case of symptoms (BBCH 30-81)
	Pests (e.g. aphids, bruchid beetle and leaf weevil)	Percentage of plants with pest attacks or other relevant assessment depending on the type of pest	Recommended	In case of occurrence/symptoms
	Plant height	In cm (from ground to the top)	Optional	After final plant height is reached
	Lodging	Percentage of the lodging plants + lodging angle on a 1 to 5 scale or other relevant scale	Considered important for the organic sector	BBCH 69 and before harvest
	Date of maturation		Recommended	
	Date of harvest		Considered important for the organic sector	
Crop performance	Yield per unit area (min. 3×1 m^2 sample plots)		Considered important for the organic sector	
	Yield components (e.g. TKW , seed moisture content etc.)		Recommended	Can be done between flowering and harvest
	Thousand-kernel weight		Recommended	
	Laboratory analyses of basic quality parameters (e.g. protein contents and test weight)		Considered important for the organic sector	
	Post-harvest quality		Optional	
	Processing quality		Recommended	

Quality of products from the trials	Nutritional quality		Optional	
	Organoleptic quality *For more information:* https://orgprints.org/38095/ VINDRAS, Camille; Sinoir, N.; Coulombel, A.; Taupier-Létage, Bruno and REY, Frederic., ITAB. Diversifood technical booklets. (2018)		Optional	

3. Cabbage family protocol

Stage of trial design	Plot-scale	Field-scale	Comments
Goal setting *For further information see Chapter 3.1*	For low-cost trials prioritize a participatory approach - Fulfil basic scientific requirements Compensation for farmers hosting the trials should be budgeted in.		
Trial scale	Pros: • **Optimal trait assessment** • **Direct comparison** across large number of varieties. Cons: • **Performance might be impaired** by the plot-scale and difficult to translate to field-scale • **Treatments are not fully independent** as e.g. plots need harvesting at the same time • **Yield assessment might not be reliable** • **Cost** (harvest and evaluation) might be high	Pros: • Direct varietal comparison in **real-world situations.** • Embedded into farm routine • Might unveil different management systems and their impact on varietal performance Cons: • **Limited number of experimental units per farm** • Need relatively **large quantity of seeds** • Might be able to test a **limited number of varieties**	It is suggested that integration between a limited number of plot-scale trials and a network of field-scale trials can be the optimal arrangement
Experimental design *(For further information see Chapter 3.3)*	• Use 30 – 50 plants per plot. • Prefer "square" plots instead of individual rows (4 rows of 15 plants rather than 2 rows of 30 plants). Number of rows depend on the planting machine (2, 3, 4 …). Observations to be made on the central row(s) of the plot if possible.		

Experimental sites	• Trial sites should be in the main growing areas of the crop and possibly cover the main pedoclimatic zones of the country • Choose certified organic trial fields - usually farmers' field • The field of the trial should be as homogeneous as possible; same pre-crop • avoid field borders (soil compaction) and greenhouse edges.	• Identify a network of farmers willing to drill and harvest separate strips of different varieties in their commercial field. • The field should ideally be as homogeneous as possible. • Generate consent forms for the participating farmers as part of a data management plan.	
Examples of site metadata *(should be adjusted according to your objectives and constraints)*	• Soil analyses (texture, N, P, K, other nutrients, pH, soil organic matter) • Cropping history of the last 5 years • Identify source of climate data – possibly have a weather station on site • Check for irrigation capacities • Consider insect-proof nets if required	• Identify soil type (texture, pH, soil organic matter, drainage) • Interview with the farmers to ascertain field cropping history, including organic/inorganic fertilisation along the rotation, main tillage operations, planting techniques, irrigation capacities insect-proof nets (if necessary) • Access soil analysis that the farmer might have performed and complement with new soil analysis if needed. • Agree with farmers to share a log of management operation on the experimental field. • If no own weather station available, identify closest climate data sources and agree about access to data.	
Agree about the assessment protocol *(see soil and crop evaluation protocol below)*	• See crop specific table below • It is of outmost importance to identify a set of essential, standard observations to be made across the different sites. • Focus on overall performance and marketable yield	• See crop specific table below • It is of outmost importance to identify a set of essential, standard observations to be made across the different sites. • Focus on overall performance and marketable yield	

<table>
<tr><td>Selection of cultivars for testing</td><td>Within the chosen growing period, two or three standard cultivars in each tested type group (early/late, green/purple) should be used at all sites;
Standard cultivars should include the most popular cultivars in organic or low input farming.
The number of cultivars should be optimized to keep costs and labour on a feasible level</td><td>Within the chosen growing period, identify at least one well known cultivar in each tested type group (early/late, green/purple) as common control across all farms
Identify a reasonable number of cultivars relevant to current crop context, including most popular cultivars as well as potential new cultivars.</td><td>In case of an on-farm network: test a large number in a plot trial and subsequently test less cultivars on field scale trials</td></tr>
<tr><td>Seed quality and procurement</td><td>For plot trials, insufficient commercial seed might be available.
Ensure quality of the seed (germination and health). Check germination rate before sowing and treat the seed if necessary (e.g. hot water or steam treatment).
Check recovery of the crop after planting (rate recovery)</td><td>Seed from one origin is preferred. Act in advance to purchase/procure a sufficient quantity of organic and/or untreated seeds for each variety
Quantity might be challenging because too high to enable use of trial seed and too low to be purchased as commercial seed.
Cooperate with seed merchants and avoid arranging seed purchase in the main seed season as delays might occur.
Assist farmers with derogations in case conventional untreated seed needs to be used
Identify whether any farmer uses farm-saved seed</td><td>In case you prefer to use farm saved seed, use seed from one origin for the whole trial as much as possible</td></tr>
<tr><td>Generate field plans</td><td>See experimental design.</td><td>See experimental design.</td><td></td></tr>
<tr><td>Sowing</td><td>1 seed per "root ball"</td><td>1 seed per "root ball"</td><td></td></tr>
<tr><td>Soil preparation and crop management</td><td>Soil preparation must follow farmer common practice and must be recorded</td><td>Soil preparation must follow farmer common practice and must be recorded</td><td></td></tr>
<tr><td>Plantation</td><td>Planting density from 14 to 16 plants/m^2</td><td>Planting density from 14 to 16 plants/m^2</td><td></td></tr>
</table>

Validation/experiment metadata		• Visit farms to ascertain that the trial is fit for purpose and that crop establishment is adequate. • Check that cultivars were planted in the agreed positions and/or be ready to correct experimental designs	
Harvest	Harvest the mature plants 1-2 (kohlrabi and cauliflower) or 2-3 times (broccoli) per week. Count the plants, divide them in marketable/non marketable (with explanation of non-marketable: sanitary, shape, size/weight)	Harvest the mature plants. Keep cultivars separated. Count the plants, divide them in marketable/non marketable (with explanation of non-marketable: sanitary, shape, size/weight)	
Statistical analysis	*For further information see Chapter 3.3*		

Soil and crop evaluation Kohlrabi

Type of data	Variables measured	Measurement/observation scale	Importance	Growth stage
Agro-climatic variables	Soil type and texture		Considered important for the organic sector	
	Soil N, P, K, Mg and pH		Recommended	
	Soil Organic Matter		Recommended	
	Climatic variables (min – max – average temperature and precipitation, etc.). *It is very important to understand what the most relevant metrics are, and what data is needed: daily, weekly, monthly?*		Recommended	During whole vegetation period
	Cropping system history (previous crop, nutrient/manure application, soil tillage, weed and disease control if applied, etc.)		Considered important for the organic sector	During whole vegetation period
Sowing	Remarks on seed quality		Optional	Before sowing
	Germination rate (calculate in %)	Number of seeds germinated/seeds sown	Optional	10 days after sowing
	Recovery rate after planting (calculate in %)	Number of living plants/planted plants	Considered important for the organic sector	10 days after planting
Crop growth and development	**General remark: For heterogeneous cultivars, choose the major type**			
	Plant vigour/vegetative development	1 to 9 scale, with 9 = very vigorous	Recommended	Twice during vegetation period
	Foliage colour	Light green to dark green	Optional	Twice during vegetation period
	Leaf shape	1 spread to 5 erected	Optional	Twice during vegetation period

	Leaf surface	1 smooth to 5 curly	Optional	Twice during vegetation period
	Disease	1 no disease to 9 high infection	Recommended	Twice during vegetation period
Harvest	Beginning, 50% and end of harvest	Dates	Considered important for the organic sector	At harvest
	Number of harvests		Recommended	At harvest
	Bulb quality	1 very low to 9 very high	Recommended	At harvest
	Bulb colour	Light green to dark green/blue/grey	Optional	At harvest
	Bulb shape	1 very flat to 9 very round	Optional	At harvest
	Bulb regularity	1 very irregular to 9 very regular	Optional	At harvest
	Stems (presence/absence) on the bulb and problem or not at harvest	1 very low to 9 very high	Optional	At harvest
	Head bud quality	1 very big buds to 9 very fine buds	Optional	At harvest
	Total number of harvested heads (firmness, no inside defect)	Number	Considered important for the organic sector	At harvest
	Number of marketable bulbs	Number	Considered important for the organic sector	At harvest
	Reasons for non-marketable heads	Description	Considered important for the organic sector	At harvest
Post-harvest quality	Organoleptic quality *For more information:* https://orgprints.org/38095/ VINDRAS, Camille; Sinoir, N.; Coulombel, A.; Taupier-Létage, Bruno and REY, Frederic., ITAB. Diversifood technical booklets. (2018)		Optional	

Soil and crop evaluation Broccoli

Type of data	Variables measured	Measurement/observation scale	Importance	Growth stage
Agro-climatic variables	Soil type and texture		Considered important for the organic sector	
	Soil N, P, K, Mg and pH		Recommended	
	Soil Organic Matter		Recommended	
	Climatic variables (min – max – average temperature and precipitation, etc.). *It is very important to understand what the most relevant metrics are, and what data is needed: daily, weekly, monthly?*		Recommended	During whole vegetation period
	Cropping system history (previous crop, nutrient/manure application, soil tillage, weed and disease control if applied, etc.)		Considered important for the organic sector	During whole vegetation period
Sowing	Remarks on seed quality		Optional	Before sowing
	Germination rate (calculate in %)	Number of seeds germinated/seeds sown	Optional	10 days after sowing
	Recovery rate after planting (calculate in %)	Number of living plants/planted plants	Considered important for the organic sector	10 days after planting
	General remark: For heterogeneous cultivars, choose the major type			
	Plant vigour/vegetative development	1 to 9 scale, with 9 = very vigorous	Recommended	Twice during vegetation period
	Foliage colour	Light green to dark green	Optional	Twice during vegetation period

Crop growth and development	Foliage homogeneity	1 to 9 scale, with 9 = very homogeneous	Optional	Twice during vegetation period
	Head homogeneity	1 to 9 scale, with 9 = very homogeneous	Optional	Twice during vegetation period
	Leaf shape	1 spread to 5 erected	Optional	Twice during vegetation period
	Leaf surface	1 smooth to 5 curly	Optional	Twice during vegetation period
	Disease	1 no disease to 9 high infection	Recommended	Twice during vegetation period
Harvest	Beginning, 50% and end of harvest	Dates	Considered important for the organic sector	At harvest
	Number of harvests		Recommended	At harvest
	Head quality	1 very low to 9 very high	Recommended	At harvest
	Head colour	Light green to dark green/blue/grey	Optional	At harvest
	Head shape	1 very flat to 9 very round	Optional	At harvest
	Head regularity	1 very irregular to 9 very regular	Optional	At harvest
	Head ramification or density; measure to pass a finger in the head	1 very low to 9 very high	Optional	At harvest
	Head compactness	1 very loose to 9 very compact	Optional	At harvest
	Head bud quality	1 very big buds to 9 very fine buds	Optional	At harvest
	Stems (presence/absence) on the bulb and problem or not at harvest	1 very low to 9 very high	Optional	At harvest
	Head bud quality	1 very big buds to 9 very fine buds	Optional	At harvest
	Total number of harvested heads	Number	Recommended	At harvest
	Number of marketable heads		Recommended	At harvest
	Total weight of harvested heads	Kg	Recommended	At harvest
	Weight of marketable heads	Kg	Recommended	At harvest
	Reasons for non-marketable heads	Description	Recommended	At harvest
	Storage capacity	1 very low to 9 very high	Optional	One week after harvest

Post-harvest quality	Organoleptic quality *For more information:* https://orgprints.org/38095/ VINDRAS, Camille; Sinoir, N.; Coulombel, A.; Taupier-Létage, Bruno and REY, Frederic., ITAB. Diversifood technical booklets. (2018)		Optional	

Soil and crop evaluation Cauliflower

Type of data	Variables measured	Measurement/observation scale	Importance	Growth stage
Agro-climatic variables	Soil type and texture		Considered important for the organic sector	
	Soil N, P, K, Mg and pH		Recommended	
	Soil Organic Matter		Recommended	
	Climatic variables (min – max – average temperature and precipitation, etc.). *It is very important to understand what the most relevant metrics are, and what data is needed: daily, weekly, monthly?*		Recommended	During whole vegetation period
	Cropping system history (previous crop, nutrient/manure application, soil tillage, weed and disease control if applied, etc.)		Considered important for the organic sector	During whole vegetation period
Sowing	Remarks on seed quality		Optional	Before sowing
	Germination rate (calculate in %)	Number of seeds germinated/seeds sown	Optional	10 days after sowing
	Recovery rate after planting (calculate in %)	Number of living plants/planted plants	Considered important for the organic sector	10 days after planting
	General remark: For heterogeneous cultivars, choose the major type			
	Plant vigour/vegetative development	1 to 9 scale, with 9 = very vigorous	Recommended	Twice during vegetation period

Crop growth and development	Foliage colour	Light green to dark green	Optional	Twice during vegetation period
	Foliage homogeneity	1 to 9 scale, with 9 = very homogeneous	Optional	Twice during vegetation period
	Head homogeneity	1 to 9 scale, with 9 = very homogeneous	Optional	Twice during vegetation period
	Leaf shape	1 spread to 5 erected	Optional	Twice during vegetation period
	Leaf surface	1 smooth to 5 curly	Optional	Twice during vegetation period
	Disease	1 no disease to 9 high infection	Recommended	Twice during vegetation period
Harvest	Beginning, 50% and end of harvest	Dates	Considered important for the organic sector	At harvest
	Number of harvests		Recommended	At harvest
	Head quality	1 very low to 9 very high	Recommended	At harvest
	Head colour	Light green to dark green/blue/grey	Optional	At harvest
	Head shape	1 very flat to 9 very round	Optional	At harvest
	Head regularity	1 very irregular to 9 very regular	Optional	At harvest
	Head ramification or density; measure to pass a finger in the head	1 very low to 9 very high	Optional	At harvest
	Head compactness	1 very loose to 9 very compact	Optional	At harvest
	Head bud quality	1 very big buds to 9 very fine buds	Optional	At harvest
	Stems (presence/absence) on the bulb and problem or not at harvest	1 very low to 9 very high	Optional	At harvest
	Head bud quality	1 very big buds to 9 very fine buds	Optional	At harvest
	Total number of harvested heads	Number	Recommended	At harvest
	Number of marketable heads	Divide harvest within 4 categories: unmarketable, small size head (11 cauliflowers in a standard box of 60 cm	Recommended	At harvest

		per 40 cm), medium size (8) and big size (6). For organic marketing, medium size is preferred For each category, number of heads per cat. and per harvest time		
	Reasons for non-marketable heads	Description	Recommended	At harvest
Post-harvest quality	Organoleptic quality *For more information:* https://orgprints.org/38095/ VINDRAS, Camille; Sinoir, N.; Coulombel, A.; Taupier-Létage, Bruno and REY, Frederic., ITAB. Diversifood technical booklets. (2018)		Optional	

4. Carrot protocol

<table>
<tr><th>Stage of trial design</th><th>Plot-scale</th><th>Field-scale</th><th>Comments</th></tr>
<tr><td>Goal setting
For further information see Chapter 3.1</td><td colspan="3">For low-cost trials prioritize a participatory approach - Fulfill basic scientific requirements

Compensation for farmers hosting the trials should be budgeted.</td></tr>
<tr><td>Trial scale</td><td>Pros:
• Optimal trait assessment
• Direct comparison across large number of varieties.
Cons:
• More resource intensive in terms of logistics, labour and data collection
• Harvest dates may vary greatly across cultivars, requiring many visits to collect data
• Treatments are not fully independent as e.g. plots need harvesting at the same time
• Costs (harvest and evaluation) might be high
• Border effect</td><td>Pros:
• Direct varietal comparison in real-world situations.
• Embedded into farm routine
• Evaluation of Genotype x Environment x Management interaction
• Less border effects
• Possibility to carry out participatory selection while Organic Heterogeneous Material (OHM) is being tested
• Yield assessment more reliable
Cons:
• Might be able to test a limited number of varieties</td><td>It is suggested that integration between a limited number of plot-scale trials and a network of field-scale trials can be the optimal arrangement</td></tr>
<tr><td>Experimental design
(For further information see Chapter 3.3)</td><td>• Plot size of minimum 5 m^2, max 10 m^2 (at least, control on 2m on the 2 central rows of the growing bed)
• Prioritise "square" plots (4 rows of 5 meters long of a single variety on a bed rather than 2 rows of 10 meters long of 2 varieties).
• Observations to be made on the central row(s) if possible</td><td>• Adopt Triadic/Tricot design
• As few varieties as possible on-farm to make it easy for the farmer
• Adopt ITC tools, such as dedicated apps to facilitate decentralised data collection</td><td>Controls should be chosen carefully, including ones well known to farmers to have a solid benchmark for evaluation and comparisons.</td></tr>
</table>

Experimental sites	• Choose certified organic farms with a good history of hosting trial fields • The agronomic practices of the farm should be respected and followed	• Identify a network of farmers willing to drill and harvest separate strips of different varieties in their commercial field. • The field should ideally be as homogeneous as possible. • Generate consent forms for the participating farmers as part of a data management plan.	Homogenous sites are preferable
Examples of site metadata *(should be adjusted according to your objectives and constraints)*	• Soil analyses (texture, N, P, K, other nutrients, pH, soil organic matter) • Cropping history of at least 3-5 earlier years (a complete rotation cycle) • Climate data – possibly have a weather station on site. If no own weather station available, identify closest climate data sources and agree about access to data • Agree with farmers to share a log of management operations on the experimental field	• Identify soil type (texture, N, P, K, other nutrients, pH, soil organic matter) • cropping history for at least 3-5 earlier years (a complete rotation cycle) • Interview with the farmers to ascertain field cropping history, including organic/inorganic fertilisation along the rotation, main tillage operations, planting techniques, irrigation capacities and use of insect-proof nets • Identify source of climate data – possibly have a weather station on site. If no own weather station available, identify closest climate data sources and agree about access to data • For on farm trials, agree with farmers to share a log of management operations on the experimental field.	Same metadata for both plot and field scale.
Agree about the assessment protocol *(see soil and crop evaluation protocol below)*	• See crop specific table below	• See crop specific table below • It is of outmost importance to identify a set of essential, standard observations to be made across the different sites. • Focus on overall performance and marketable (and non-marketable) yield	
Selection of varieties for testing	Distinction to be made between: ○ Field/greenhouse production (with autumn or winter sowing)	• Same as per plot scale, however as the number of varieties that can be hosted at field scale is greatly reduced, choice should focus on most promising	Controls should be chosen carefully, including varieties well known to farmers, to have a solid

	○ Early or seasonal production (late winter or spring sowing) ○ Carrots harvested in bunches or bulk harvest. • Each type has specific growing periods or management operations so specific trials are needed. • Within each group, one or two standard varieties should be used at all sites; standard varieties should include the most popular ones for organic or low input farming, including some which are already on recommended variety lists as benchmarks.	candidates and controls should be well known both by farmers and researchers.	benchmark for evaluation and comparisons. In case of mechanical harvesting, specific control varieties must be used, and specific traits have to be observed (broken roots, foliage strength)
Seed quality and procurement	• Seed material should correspond to the Basic seed category requirements. • Check germination rate and treat the seeds if necessary (e.g. hot water or steam treatment). • Check recovery of the crop after planting (rate recovery)	Preferably use certified seed. Act in advance to purchase/procure a sufficient quantity of organic and/or untreated seeds for each variety • Quantity might be challenging because too high to enable use of trial seed and too low to be purchased as commercial seed. • Cooperate with seed merchants and avoid arranging seed purchase in the main seed season as delays might occur. • Assist farmers with derogations in case conventional untreated seed needs to be used • Identify whether any farmer uses farm-saved seed.	
Generate field plans	See experimental design.	See experimental design.	

<table>
<tr>
<td rowspan="2">Sowing density</td>
<td>• Depends on type of carrot crop and purpose, and machinery for sowing and hoeing.
• Use best practices adopted in the region. Distance between rows often dictated by the farm equipment used for weed control.
• Density : 15 000 to 20 000 seeds for 100 m^2 (60 to 100 seeds per m in a row, with 20 to 50 cm between rows).</td>
<td>• For field scale, it is recommended to use the sowing density normally adopted by the farm for that type of carrot.
• Distance between rows often dictated by the type of farm equipment used for weed control.</td>
<td rowspan="2">As a general rule, if participatory evaluations are foreseen, passages between rows and around rows’ ends should be kept in mind, allowing enough space (e.g. 1.5m between rows)

/!\ In many parts of Europe, net protection must be installed after sowing, and often maintained during the whole growing period, to prevent carrots from carrot fly (Psila rosae)/!\</td>
</tr>
<tr>
<td colspan="2">Before sowing, one (or more) false seedbed is highly recommended for carrot. Thermal weed control is also recommended if the adapted equipment is available on the farm or experimental station.</td>
</tr>
<tr>
<td rowspan="2">Harvest</td>
<td colspan="2">Harvest the ripe plants when needed. Count the plants and/or bunches, divide them in marketable/non marketable (provide explanation of reason for non-marketability: sanitary, appearance, size/weight), and weigh them.</td>
<td rowspan="2">For <u>bunch harvesting</u>: a standard number of roots per bunch or/and a minimum bunch weight have to be defined for all experimental sites!

In case of <u>mechanical harvesting</u>, specific control varieties must be used, and specific traits have to</td>
</tr>
<tr>
<td>Harvest depending on purpose (bunches for fresh consumption or bulk for storage) and ripeness.

For each plot, record:

• date of harvest
• number of plants/bunches harvested
• shape, number, size and weight of marketable roots
• quality description: appearance of the variety (root, leaves), adaptation to</td>
<td>Harvest depending on purpose (bunches or storage) and ripeness.

For each plot, record:

• date of harvest
• number of plants/bunches harvested
• shape, number and weight of marketable roots
• quality description: appearance of the variety (root, leaves), adaptation to brunch harvesting, defects (fork shape, green collar …)</td>
</tr>
</table>

	brunch harvesting, defects (fork shape, green collar…) number, weight and reason for non-marketable roots (for example, number of broken roots in case of mechanical harvesting)	• number, weight and reason for non-marketable roots (for example, number of broken roots in case of mechanical harvesting). At field scale, this level of assessment can be carried out on a limited number of randomly picked plants/ bunches within each variety.	be observed (broken roots, foliage strength)
Visual evaluation	Traits that can be evaluated on a scale from 1 to 4 are: • plant vigour • susceptibility to diseases and pests • degree of homogeneity within the plot • perceived yield • general score	Traits that can be evaluated on a scale from 1 to 4 are: • plant vigour • susceptibility to diseases and pests • degree of homogeneity within the plot • perceived yield • general score	At field scale, visual observations can be limited to the randomly picked plants which get assessed in more detail.
Data collection	• Use paper field book or filed book app • Quantitative data should be recorded by a technician/researcher • Participatory visual evaluation can involve a group of farmers.	• Use paper field book or filed book app • Quantitative data should be recorded by a technician/researcher • Participatory visual evaluation can involve a group of farmers.	
Statistical analysis	*For further information see Chapter 3.3*		

Soil and crop evaluation

Type of data	Variables measured	Measurement/observation scale	Importance	Growth stage
Agro-climatic variables	Soil type and texture		Considered important for the organic sector	
	Soil N, P, K, Mg and pH		Recommended	
	Soil Organic Matter		Recommended	
	Climatic variables (min – max – average temperature and precipitation, etc.). *It is very important to understand what the most relevant metrics are, and what data is needed: daily, weekly, monthly?*		Recommended	During whole vegetation period
	Cropping system history (previous crop, nutrient/manure application, soil tillage, weed and disease control if applied, etc.)	Rotation scheme, products and inputs used, dates of application	Considered important for the organic sector	During whole vegetation period
Crop growth and development	Germination rate	Percentage (No. seeds sown/No. seeds germinated)	Considered important for the organic sector	10 days after sowing
	Sowing date	Date	Considered important for the organic sector	
	Emergence date	Date	Considered important for the organic sector	
	Density at emergence/recovery rate after emergence To be compared to sowing density	Date	Considered important for the organic sector	Emergence + a few days
	Plant vigour/vegetative development	1 to 9 scale, with 9 = very vigorous	Recommended	Twice during vegetation period

	Foliage description	1 to 9 scale, with 9 = very homogeneous	Optional	Twice during vegetation period
	Ripening (cycle length)	Date	Considered important for the organic sector	Depending on marketable stage for each type
	Date of Harvest	Date	Considered important for the organic sector	
	Overall crop description	At harvest	Considered important for the organic sector	
	Disease	1 no disease to 9 high infection	Recommended	Twice during vegetation period
Crop performance	Yield	T/ha (or kg/m^2) or number of bunches/m^2	Considered important for the organic sector	
	Yield components For non-marketable yield, specify reason (pests, broken or deformed roots …)	Kg/m^2, No. of roots	Considered important for the organic sector	Marketable yield, non-marketable yield
Post-harvest quality	Storage capacity	1 very low to 9 very high	Optional	One week and one month after harvest (in case of refrigerated storage) One month (and two months) after maturity in case of "in soil" storage
	Organoleptic quality *For more information:* https://orgprints.org/38095/ VINDRAS, Camille; Sinoir, N.; Coulombel, A.; Taupier-Létage, Bruno and REY, Frederic., ITAB. Diversifood technical booklets. (2018)		Optional	

5. Potato protocol

Stage of trial design	Plot-scale	Field-scale	Comments
Goal setting *For further information see Chapter 3.1*	For low-cost trials prioritize a participatory approach - Fulfil basic scientific requirements		
Trial scale	Pros: • **Optimal trait assessment** • **Direct comparison** across large number of varieties. • **Complex experiments** are more feasible on small plots (e.g. effect of irrigation, fertiliser, inoculum, etc. and their combination) Cons: • **Performance might be impaired** by the plot-scale and difficult to translate at field scale • **Cost** might be high	Pros: • Direct varietal comparison in **real-world situations.** • Embedded into farm routine • Might unveil different management systems and their impact on varietal performance Cons: • **Limited number of experimental units per farm** • Need relatively **large quantity of seed tubers** • Might be able to test a **limited number of varieties and traits**	It is suggested that integration between a limited number of plot-scale trials and a network of field-scale trials can be the optimal arrangement
Experimental design	*For further information see Chapter 3.3*		
Experimental sites	• Trial sites should be in the main growing areas of the crop and possibly cover the main pedoclimatic zones of the country • Choose certified organic trial fields - usually farmers' field • The field of the trial should be as homogeneous as possible; same pre-crop, beware of the field	• Identify a network of farmers willing to drill and harvest separate strips of different varieties in their commercial field. • The field should ideally be as homogeneous as possible. • Generate consent forms for the participating farmers as part of a data management plan.	

	edges, where machinery turns thus compacting the soil • Moist soil or irrigation possibility		
Examples of site metadata *(should be adjusted according to your objectives and constraints)*	• Soil analyses (texture, N, P, K, other nutrients, pH, soil organic matter). • Pre-crop and cropping history for the last few years. • Identify source of climate data – possibly have a weather station on site.	• Identify soil type (texture, pH, soil organic matter, drainage) • Interview with the farmers to ascertain field cropping history, including organic/inorganic fertilisation along the rotation, main tillage operation. • Access soil analysis that the farmer might have performed and complement with new soil analysis if needed. • Agree with farmers to share a log of management operation on the experimental field. • If no own weather station available, identify closest climate data sources and agree access to data.	
Agree about the assessment protocol *(see soil and crop evaluation protocol below)*	• Focus on varietal traits especially tuber phenology, disease resistance	• Identify a set of essential, standard metrics across the different sites • Focus on overall performance, actual yield and quality	If plot-field-scale are integrated, assessment on specific traits can be intensified at the plot trial and kept at a minimum essential on the farm scale
Selection of varieties for testing	• Two or three standard varieties in each tested maturity group (early/medium early / medium late/late) should be used at all sites; standard varieties should include the most popular varieties in organic or low input farming.	• Identify a reasonable number of varieties relevant to current crop context, including most popular varieties as well as potential new varieties.	The number of varieties should be optimized to keep costs and labour on a feasible level
Seed quality and procurement	• Seed material should correspond to Basic seed category requirements.	Use commercial seed. Act in advance to purchase/procure a sufficient quantity of organic and/or untreated seeds for each variety	Check required quantity of seed material according to planed trial design and plot

		• Cooperate with seed merchants and avoid arranging seed tuber purchase in the main season as delays might occur, order as soon as possible (if feasible already in September) • Assist farmers with derogations in case conventional untreated seed needs to be used	size. Preferable seed tuber size – 35-55 mm. In case it's feasible use pre-sprouted seed tubers Important: the seed-tuber need has to be ordered as soon as possible (maybe already in September)
Generate field plans	See experimental design.	Varieties should be drilled as strips wide enough to be harvested separately with farm machinery. At least one variety should be replicated at least twice in each farm.	
Planting density	4-6 tubers per m^2 Suggested row distance 70-75 cm Suggested planting distance 30 cm	Depending on planter and seed tuber size, about 3-4 t per ha or 30-40.000 tubers per ha	Density depends on seed tuber size and distance between rows.
Statistical analysis	*For further information see Chapter 3.3*		

Soil and crop evaluation

Type of data	Variables measured	Measurement/observation scale	Importance	Growth stage
Agro-climatic variables	Soil type		Recommended	
	Soil texture		Considered important for the organic sector	
	Soil N P, K, and pH		Recommended	
	Soil Organic Matter		Recommended	
	Climatic variables (min – max – average temperature and precipitation, etc.). *It is very important to understand what the most relevant metrics are, and what data is needed: daily, weekly, monthly?*		Recommended	
	Cropping system history (previous crop, nutrient/manure application, soil tillage, weed and disease control if applied, etc.)	Dates of application, doses, etc.	Considered important for the organic sector	
Crop growth and development	Planting date	Date	Considered important for the organic sector	
	Emergence	DAP – days after planting (count days between planting date and observation date)	Recommended	Stems break through soil surface (BBCH 07-09)
	Full flowering	DAP	Recommended	50% of flowers in the first inflorescence open (BBCH 64)
	Leaf diseases (late blight) damages	Percentage of damaged leaf area from total leaf area or / and % of plants with symptoms	Strongly recommended	Crop cover (BBCH 31-39)

		Once during diseases (late blight) epidemic, when differences between varieties are observed Or Dynamic of diseases development, assessments each 7-10 days when first symptoms appears		
	Pests – Colorado beetle	Check damages, % of total leaf area	Optional	
	Date of haulm killing	Date	Considered important for the organic sector	Tuber maturity (BBCH 49)
	Date of harvest	Date	Considered important for the organic sector	Harvested tubers (BBCH 99)
Crop performance	Tuber yield per unit area (min. 10 plants) Preferably plot yield	T/ha or kg/m^2	Considered important for the organic sector	
	Marketable tuber yield (marketable size largely varies between countries), without damaged and deformed tubers	T/ha or kg/m^2	Recommended	
	Tuber evaluation (on e.g.50 random selected tubers per plot) main diseases, damage, deformation, etc.		Optional	
	Dry matter (or starch content) in tubers via weight in air and water	Percentage FW	Optional	
Quality of products from the trials	Organoleptic quality (taste of boiled tubers) *More information:* https://orgprints.org/38095/ VINDRAS, Camille; Sinoir, N.; Coulombel, A.; Taupier-Létage, Bruno and REY, Frederic., ITAB. Diversifood technical booklets. (2018)	Score between 1 and 9, 9 – very tasty, 1 – unpalatable.	Recommended	
	Nutritional quality (protein, vitamins, glycoalkaloids etc.)		Optional	

6. Tomato protocol

Stage of trial design	Plot-scale	Field-scale/large plots	Comments
Goal setting *For further information see Chapter 3.1*	For low-cost trials prioritize a participatory approach (Compensation for farmers hosting the trials should be calculated in the budget. Only small pilot trials (<50 plants) may be accepted as in kind contribution from farmers) - Fulfil basic scientific requirements		
Trial scale	Pros: • **Optimal trait assessment** • **Direct comparison** across large number of varieties. • **Optimal for experimental aims** Cons: • **More resource intensive** in terms of logistics, labour and data collection • **A strong commitment from all the stakeholders involved is essential** • **Harvest dates may vary greatly** across cultivars, requiring many visits to collect data • **Border effect**	Pros: • Direct varietal comparison in **real-world situations.** • Evaluation of Genotype x Environment x Management interaction • Less border effects • **Possibility to carry out participatory selection** while Organic Heterogeneous Material (OHM) is being tested • **Yield assessment** more reliable Cons: • Might be able to test a **limited number of varieties**	It is suggested that integration between a limited number of plot-scale trials and a network of field-scale trials can be the optimal arrangement Important to keep a strong link with the network, avoiding changes (Hard to train in PPB)
Experimental design *For further information see Chapter 3.3*	• plot size of minimum 8 plants (in case of clearly defined varieties, landraces or ecotypes), max 20 plants (in case of e.g. OHM)	• Adopt Triadic/Tricot design • As few varieties as possible on-farm to make it easy for the farmer • Adopt ITC tools, such as dedicated apps to facilitate decentralised data collection	

Experimental sites	• Trial sites should be in the areas relevant for the particular type of tomato (industry, fresh market, etc.) • choose certified organic farms with a good history of hosting trial fields • the agronomic practices of the farm should be respected and followed.	• Trial sites should be in the areas relevant for the particular type of tomato (industry, fresh market, etc.) • choose certified organic farms with a good history of hosting trial fields • the agronomic practices of the farm should be respected and followed.	Homogenous sites are preferable, however **statistical spatial analysis** can compensate for heterogeneous locations, typical for marginal areas, where organic farms are often located. (e.g. R package SpATS) When possible, choose and compare trials sites using different practices for a broader approach (e.g. site or practice effect)
Examples of site metadata *(should be adjusted according to your objectives and constraints)*	• Soil analyses (texture, N, P, K, other nutrients, pH, soil organic matter, salinity/conductivity) • Water analysis (general with ions, salinity/conductivity, etc.) • cropping history for at least 3-5 earlier years (a complete rotation cycle) • Climate data – possibly have a weather station on site. If no own weather station available, identify closest climate data sources and agree about access to data • Agree with farmers to share a log of management operation on the experimental field.	• Soil analysis (texture, N, P, K, other nutrients, pH, soil organic matter, salinity/conductivity). • Water analysis (general with ions, salinity/conductivity, etc.) • cropping history for at least 3-5 earlier years (a complete rotation cycle) • Climate data – possibly have a weather station on site. If no own weather station available, identify closest climate data sources and agree about access to data • Agree with farmers to share a log of management operation on the experimental field.	Same metadata for both plot and field scale.
Selection of varieties for testing	• The first distinction to be made is between determined industry tomato and undetermined tomato for the fresh market. (Also, a third type can be considered in Mediterranean areas: long shelf life or hanging tomatoes)	Same as in case of plot scale, however as the number of varieties that can be hosted on a field scale is strongly limited, hence the focus should be on most promising candidates, and controls should be well known both by farmers and researchers.	Controls should be chosen carefully, including i) commercial controls, ii) varieties representative of the main varietal types and iii) ones well known to farmers to have a solid

	• The second important distinction is between open field and green house. • Within each group, the most representative varietal types should be included, two or three standard varieties should be used at all sites; standard varieties should include the most popular varieties in organic or low input farming, considering some already on recommended variety lists as benchmarks.		benchmark for evaluation and comparisons.
Plant propagating material and procurement	• Seed material should correspond to the Basic seed category requirements. • For tomatoes farmers are often resorting to nursery for transplants, therefore collaborative work with them is essential.	• Preferably use certified seed. • Team with nurseries in the locality to produce transplants needed.	Tomatoes are most often purchased by farmers as young plants: teaming with nurseries and using standardised propagation procedures is essential (size of plugs, type of compost, organic treatments, etc.)
Planting density	• Depends on type of tomato crop involved as well as on the growing conditions. Use the best practices adopted in the region. In case of plots with >14 plants, consider splitting between two opposite rows to allow passage in the middle for better evaluation. • Distance between rows is often determined by the farm equipment used for weed control.	• For field scale, it is recommended to use the planting density normally adopted by the farm for that type of tomato. • Distance between rows is often determined by the type of farm equipment used for weed control.	As a general rule, if participatory evaluations are foreseen, passages between rows and around rows' ends should be kept in mind, avoiding too dense rows (e.g. at least 1 m between rows)
Harvest	Harvest fruits of first three trusses at regular intervals. For each plot record: • date of harvest • number of plants harvested • number and weight of marketable berries	Harvest fruits of first three trusses at regular intervals. For each plot record: • date of harvest • number of plants harvested • number and weight of marketable berries	Different protocols apply to determined industry varieties: in this case the whole plant is harvested and green berries are also counted and weighted.

	• number and weight of non-marketable or injured berries • fruit firmness	• number and weight of non-marketable or injured berries At field scale, this level of assessment can be carried out on a limited number of randomly (representatively) picked plants per variety.	
Visual evaluation	Traits that can be evaluated on a scale e.g. from 1 to 4 are: • plant vigour and size • leaf coverage • density and vigour of lateral shoots • pruning needs • susceptibility to main diseases • degree of homogeneity within the plot • perceived yield • general score Also distribution of fruit setting (concentrated on the basis, on 2-3 points of the plant, well distributed along the plant, etc.) and harvesting can be evaluated. Participatory breeding with other stakeholders: retailers, end user (e.g. consumers, chefs) may require user-scale evaluations and taste panels.	Traits that can be evaluated on a scale e.g. from 1 to 4 are: • plant vigour and size • leaf coverage • density and vigour of lateral shoots • susceptibility to main diseases • degree of homogeneity within the plot • perceived yield • general score Also distribution of fruit setting (concentrated on the basis, on 2-3 points of the plant, well distributed along the plant, etc.) and harvesting can be evaluated. Participatory breeding with other stakeholders: retailers, end user (e.g. consumers, chefs) may require user-scale evaluations and taste panels.	At field scale, visual observations can be limited to the randomly picked plants which get assessed in more detail.
Data collection	• Use paper field book or filed book app. • Quantitative data should be recorded by a technician/researcher. • Participatory visual evaluation can involve a group of farmers and other stakeholders (consumers, chefs, retailers, etc.)	• Use paper field book or filed book app. • Quantitative data should be recorded by a technician/researcher. • Participatory visual evaluation can involve a group of farmers and other stakeholders (consumers, chefs, retailers, etc.)	When possible, determine soluble solids and total acidity using refractometer.
Statistical analysis	*For further information see Chapter 3.3*		

Soil and crop evaluation

Type of data	Variables measured	Measurement/observation scale	Importance	Growth stage
Agro-climatic variables	Soil type and texture		Recommended	
	Soil N, P, K, Ca, pH, salinity		Recommended	
	Soil Organic Matter		Recommended	
	Water analyses for conductivity/salinity and main ions		Recommended	
	Climatic variables (min – max – average temperature and precipitation, etc.). *It is very important to understand what the most relevant metrics are, and what data is needed: daily, weekly, monthly?*		Recommended	
	Cropping system history (previous crop, nutrient/manure application, soil tillage, weed and disease control if applied, etc.)	Rotation scheme, products and inputs used, dates of applications	Considered important for the organic sector	
Crop growth and development	Sowing date	Date	Considered important for the organic sector	
	Planting date	Date	Considered important for the organic sector	
	Full flowering	Date	Recommended	50% of plants in the plot have flowers on first truss fully open For industry tomato normally the second truss is considered
	Fruit setting	Date	Optional	50% of plants in the plot have set fruit on the first truss

	Fruit colouring	Date	Optional	50% of plants in the plot have switched from green to yellow on the fruit on the first truss
	Ripening	Date	Considered important for the organic sector	50% of plants in the plot have switched from yellow to red (or the typical ripening colour of the cultivar) on the fruit on the first truss
	Date of Harvest	Date	Considered important for the organic sector	This may vary depending on the type of tomato (determined for industry, all at once; indetermined for fresh market several passages, see above)
Crop performance	Yield	Kg/plant, T/ha	Considered important for the organic sector	
	Yield components (Marketable yield, non-marketable yield, unripe berries) For non-marketable yield specify reason (split berries, rot, etc.)	Kg/plant, number of berries	Considered important for the organic sector	
	Quality (e.g. soluble solids level in ripe berries)	Degrees Brix	Recommended	
	Organoleptic quality *For more information:* https://orgprints.org/38095/ VINDRAS, Camille; Sinoir, N.; Coulombel, A.; Taupier-Létage, Bruno and REY, Frederic., ITAB. Diversifood technical booklets. (2018)		Optional	

7. Apple protocol

Stage of trial design	Plot-scale	Field-scale	Comments
Goal setting	For low-cost trials prioritize a participatory approach - Fulfil basic scientific requirements *For further information see Chapter 3.1*		
Trial scale	Pros: • **Optimal trait assessment** • **Direct comparison** across large number of varieties. Cons: • **Performance might be impaired** by the plot-scale and difficult to translate to field-scale • **Treatments are not fully independent** as e.g. plots need harvesting at the same time • **Cost** might be high	Pros: • Direct varietal comparison in **real-world situations.** • Embedded into farm routine • Might unveil different management systems and their impact on varietal performance Cons: • **Limited number of experimental units per farm** • Need relatively **large quantity of seeds** • Might be able to test a **limited number of varieties**	It is suggested that integration between a limited number of plot-scale trials and a network of field-scale trials can be the optimal arrangement
Experimental design	*For further information see Chapter 3.3*		
Experimental sites	• Trial sites should be in the main growing areas of the crop and possibly cover the main pedoclimatic zones of the country • Choose certified organic trial fields - usually farmers' field and farmers' storage facilities • The field of the trial should be as homogeneous as possible; same pre-crop, beware of the field edges, where machinery turns thus compacting the soil	• Identify a network of farmers willing to plant separate strips of different varieties in their commercial field. • The field should ideally be as homogeneous as possible. • Generate consent forms for the participating farmers as part of a data management plan.	Recommended for on station testing at least 2x5 trees/variety and for plot scale at least 3-5 trees per plot, under standard organic plant management It is important to choose the same rootstocks not more than 2, to compare better data and

			information among different farms involved
Examples of site metadata *(should be adjusted according to your objectives and constraints)*	• Soil analyses (texture, N, P, K, other nutrients, pH, soil organic matter). • Cropping history of at least 5 earlier years. • Identify source of climate data – possibly have a weather station on site.	• Identify soil type (texture, pH, soil organic matter, drainage) • Interview with the farmers to ascertain field cropping history, including organic/inorganic fertilisation along the rotation, main tillage operations. • Access soil analysis that the farmer might have performed and complement with new soil analysis if needed. • Agree with farmers to share a log of management operation on the experimental field. • If no own weather station available, identify closest climate data sources and agree about access to data.	
Agree about the assessment protocol *(see soil and crop evaluation protocol below)*	See below • Focus on varietal traits especially phenology, disease and pest progression, yield, fruit quality assessment and shelf-life	• See crop specific table below; it is of outmost importance to identify a set of essential, standard observations to be made across the different sites. • Focus on overall performance, yield, fruit quality and shelf-life	If plot-field-scale are integrated, assessment on specific traits can be intensified at the plot trial and kept at a minimum essential on the farm scale
Selection of varieties for testing	• Two or three standard varieties in each tested maturity group (early/late) should be used at all sites; standard varieties should include the most popular varieties in organic or low input farming • The number of varieties should be optimized to keep costs and labour on a feasible level	• Identify one variety as common control across all farms • Identify a reasonable number of varieties relevant to current crop context, including most popular varieties as well as potential new varieties	If plot-field scale are integrated, the plot trial can serve as a platform to test larger number of varieties that can subsequently be included in the field-scale network

			(which may not be able to test them all)
Seed quality and procurement	• Negative selection at seedling bed and positive selection at nursery for vigorous and tolerant plants to pest and diseases	Use commercial plants from certified nurseries . Anticipate in order to purchase/procure enough quantity of organic and/or untreated plants for each variety • Pre-order your plants from nurseries the season before. Assist farmers with derogation in case conventional untreated nursery plants need to be used • Identify whether any farmer uses own propagation material	Recommendation: select varieties (up to ten) to test on station(agronomic and genetic performance) for at least 3 years and then selected varieties can be tested on farm(3-4 varieties /farm. The performance for the genotypes can be compared on their own roots to the performance on different rootstocks (the semi-vigorous (MM.106, M.7), semi-dwarf (M.26, MM.102, Ottawa 3) and dwarf (M.9) vigour range)
Planting density	Planting density according to the rootstock used (tall, semi dwarf ,dwarf), pruning system and distance recommendations	Be prepared to assist farmers in planting trees at recommended distances and pruning system	Recommendation examples for trees on MM.106 rootstock: #1. at a spacing of 5 meters x 1.8 meters (1.111 trees/ha), and trained to a free-standing central leader system. #2. at a spacing of 3.6 m x 1.0 m (2.777 trees/ha) and trained to a vertical trellis For tree testing density could be more (e.g. 4.000 trees/ha)

Soil preparation		Soil preparation must follow farmer common practice and must be recorded.	
Plant protection		Minimal to avoid tree loss	
Harvest		Make sure yield recording can be done as accurately as possible and be ready to provide assistance to farmers during harvest. Every farmer might have a different yield-measuring system.	
Post-harvest		Make sure that fruits are stored in proper storage facilities recommended owned by the farmer at his place	
Statistical analysis	*For further information see Chapter 3.3*		

Soil and crop evaluation

Type of data	Variables measured	Measurement/observation scale	Importance	Growth stage
Agro-climatic variables	Soil type and texture		Considered important for the organic sector	
	Soil N, P, K, Mg and pH		Recommended	
	Soil Organic Matter		Recommended	
	Climatic variables (min – max – average temperature and precipitation, etc.).		Recommended	
	Cropping system history (previous crop, nutrient/manure application, soil tillage, weed and disease control if applied, etc.)		Considered important for the organic sector	
Crop growth and development	Crop seedling vigour	Score; plant height	Recommended	At seedling stage
	Flowering intensity	1 to 9 scale	Recommended	
	Tendency to alternate bearing	1 to 9 scale	Recommended	
	Growth cycle length (flowering date, harvest date) (e.g. early/medium/late variety)	No. of days to flowering and to harvest	Considered important for the organic sector	At flowering and harvest time
	Storage life at 3-5 ºC	Days	Recommended	After harvest
	Weed community		Optional	All growing season phases
	Overall performance against diseases		Considered important for the organic sector	All season phases and during storage period
	Diseases indicatory: • Fire blight (*E. amylovora*) • Apple scab (*V. inaequalis)*	Disease incidence and disease severity – use of standard scales	Strongly Recommended	In case of symptoms

	• Powdery mildew (*P. leucotricha)* • Leaf blotch (*Marssonina*) • Canker (*Nectria)* • Fire blight (*Erwinia amylovora*) • Storage diseases			
	Pests indicatory: • woolly apple aphid (*Eriosoma lanigerum*) • rosy apple aphid (*Dysaphis plantaginea*) • green apple aphid (*Aphis pomi*) • rosy leaf-curling aphid (*Dysaphis devecta*) • fruit peel moth (*Adoxophyes reticulana*) • pear-leaf blister moth (*Leucoptera scitella*) • spotted tentiform leafminer (*Phyllonorycter blancardella*) • codling moth (*Cydia pomonella*) • *Stefanitis pyri*		Recommended	In case of occurrence/symptoms
	Sensitivity to treatments (sulphur, copper)		Recommended	Pre- and post-harvest
	Pre-harvest dropping		Recommended	Maturation
	Date of maturation		Recommended	
	Date of harvest	Date	Considered important for the organic sector	
Crop performance	Yield per tree and per unit area		Considered important for the organic sector	
	Average fruit weight		Considered important for the organic sector	At harvest
Quality of products from the trials	Laboratory analyses of basic quality parameters (Brix, total acidity, pH, total phenols)		Considered important for the organic sector	
	Post-harvest quality (e.g. storability of fresh produce)		Recommended	At least 4 months in cold storage
	Nutritional quality	Laboratory assessment	Optional	
	Organoleptic quality *For more information:*		Optional	

	https://orgprints.org/38095/ VINDRAS, Camille; Sinoir, N.; Coulombel, A.; Taupier-Létage, Bruno and REY, Frederic., ITAB. Diversifood technical booklets. (2018)			