BENEFITS.BIOBREEDING

# Benefits of organic breeding: taking stock and raising awareness

## Report on Activity 1: Value chain expert consultation

Authors: Claudia Meier, Mariateresa Lazzaro, Marlene Sander

Date: 15.11.2024

Research Institute of Organic Agriculture FiBL | Ackerstrasse 113 | Postfach 219
5070 Frick | Switzerland | Phone +41 62 865 72 72 | info.suisse@fibl.org | www.fibl.org

# Table of content


**1. Summary** ..... **5**
**2. Background, Objectives and Scope** ..... **6**
**3. Benefits and costs evaluation** ..... **8**
3.1 General approach and methodology ..... 8
*3.1.1 Indicator development* ..... *10*
*3.1.2 Limitations of the general approach* ..... *11*
3.2 Case study 1: FURAT wheat population in Italy as example of potential Organic Heterogeneous Material (OHM) ..... 11
*3.2.1 Case study description* ..... *11*
*3.2.2 Case-specific methodology for the selection and evaluation of indicators* ..... *13*
*3.2.3 Results of the explorative expert interviews* ..... *17*
*3.2.4 List of indicators and statements* ..... *20*
*3.2.5 Evaluation of indicators and statements* ..... *20*
*3.2.5.1 Financial benefits and costs in the FURAT value chain* ..... *20*
*3.2.5.2 Advantages and disadvantages of using OHM cultivars in wheat production 22*
*3.2.6 Discussion* ..... *30*
*3.2.7 Case study summary* ..... *36*
3.3 Case study 2: Open pollinated beetroot cultivar in Germany, potential Organic Variety (OV) ..... 39
*3.3.1 Case study Description* ..... *39*
*3.3.2 Case study specific methodology for the selection and evaluation of indicators41*
*3.3.3 Results of the explorative expert interviews* ..... *44*
*3.3.4 List of indicators and statements* ..... *47*
*3.3.5 Evaluation of indicators and statements* ..... *48*
*3.3.5.1 Financial benefits and costs in the value chain for organically bred OP beetroot varieties 48*
*3.3.5.2 Advantages and disadvantages of organically bred, open pollinated beetroot varieties 52*
*3.3.6 Discussion* ..... *61*
*3.3.7 Case study summary* ..... *63*
3.4 Case study 3: Landrace/ heirloom cultivar in Switzerland ..... 65
*3.4.1 Case study description* ..... *65*
*3.4.2 Case study specific methodology for the selection and evaluation of indicators66*
*3.4.3 Results of the workshop* ..... *69*
*3.4.4 List of indicators* ..... *73*
*3.4.5 Case study summary* ..... *74*
**4. Publication "Cultivated Biodiversity"** ..... **75**
**5. Conclusions** ..... **76**
**6. References** ..... **78**
**7. Annex 1** ..... **85**

8. **Annex 2** ........ 89
9. **Annex 3** ........ 96

## List of Tables

Table 1: List of interviewed experts (indicated in the Table as "E"), including their profession and affiliation for the FURAT case. ........ 14
Table 2: Interview guideline FURAT wheat case ........ 15
Table 3: Structure workshop FURAT indicator evaluation (24 May 2024) ........ 16
Table 4: Potential (perceived) benefits of using OHM cultivars in wheat cultivation. ........ 18
Table 5: Potential (perceived) costs of using OHM cultivars in wheat cultivation. ........ 19
Table 6: Financial benefits and costs in the bread wheat FURAT value chain in Toscany (Italy) assessed in 2024 ........ 21
Table 7: List of benefits of using OHM perceived by the stakeholders. ........ 36
Table 8: List of costs of using OHM perceived by the stakeholders. ........ 38
Table 9: Experts (indicated as "E") interviewed for beetroot case ........ 41
Table 10: Interview guideline for beetroot case ........ 42
Table 11: Study participants beetroot case (B = breeder, S = seed producer, F = farmer, P = processor) ........ 43
Table 12: Potential benefits of organically bred OP cultivars as of expert interviews ........ 44
Table 13: Potential costs of organically bred OP cultivars as of expert interviews ........ 46
Table 14: Financial benefits and costs in the value chain for organically bred OP beetroot varieties ........ 48
Table 15 Benefits of organically bred OP beetroot cultivars as of case study interviews ........ 63
Table 16 Costs of organically bred OP beetroot cultivars as of case study interviews ........ 64
Table 17: Workshop program ........ 67
Table 18: Structure of the posters and guiding questions. ........ 68
Table 19: Results of exercise 2 – costs and benefits of landraces. ........ 70
Table 20: Results of exercise 3 – slogans to promote the onion landrace 'Rouge de Genève' (brainwriting exercise). ........ 71
Table 21: Costs and benefits of landraces ........ 74

Table 22: List of indicators and statements case study 1: OHM Italy .......................... 85
Table 23: List of indicators and statements case study 2: OV beetroot Germany ...... 89
Table 24: List of indicators and statements case study 3: Landraces Switzerland ........................................................ 96

## List of Figures

Figure 1: Benefits.Biobreeding – three focus cases and three activities. ............... 6
Figure 2: Methodological approach of activity 1 (value chain expert consultation) ........................................................ 9
Figure 3: "FURAT tenero Floriddia popolazione" field for organic seed production on the farm of Rosario Floriddia in Peccioli, Tuscany, Italy (Photo: Marlene Sander, June 2023). ........................................................ 13
Figure 4: Plants of "FURAT tenero Floriddia popolazione" in a field for organic seed production on the farm of Rosario Floriddia in Peccioli, Tuscany, Italy . Phenotypic differences between single plants within the cultivar can be clearly seen. (Photo: Marlene Sander, June 2023) ........................................................ 13
Figure 5: Value chain of organic beetroot for juice (own illustration). ................ 40
Figure 6: Varieties Robuschka (Kultursaat e.V.) and Gesche (Saat:gut e.V). Pictures are taken from the Bioverita website (https://bioverita.ch/en/varieties/vegetable-varieties/ ) ........................................ 41
Figure 7: Organic LR and F1-hybrid onions ........................................................ 65

# 1. Summary

This report presents the methodology and results of Activity 1 (value chain expert consultation) of the project BENEFITS.BIOBREEDING that aims to take stock of and raise awareness on the benefits of organic plant breeding for society and the environment.

The background for this work is the lack in awareness among value chain actors, including consumer-citizens, with respect to organic plant breeding and the difficulty in promoting the common goods organic plant breeding provides (e.g. increase in agrobiodiversity).

The project BENEFITS.BIOBREEDING consists of three separate activities:

- **Activity 1: Value chain expert consultation (focus of this report);**
- Activity 2: Organic consumer consultation;
- Activity 3: Outreach and awareness raising to citizens and value chain actors.

In Activity 1 (value chain expert consultation), which is the focus of the current report, we involved value chain actors of three selected focus cases to identify and evaluate the benefits of organic breeding. Based on this output, we created consumer-citizens oriented messages to communicate these benefits and we complied them in a dissemination publication (https://www.biobreeding.org/ressources.html#c39335).

The three focus cases for the benefits-costs assessment were selected among the initiatives that are part of the Horizon Europe project LiveSeeding (https://www.liveseeding.eu/), each including a relevant selection/ breeding program and an established value chain. The three focus cases are:

- Breeding program: Development of a Composite Cross Population (CCP), as a potential example of **Organic Heterogeneous Material (OHM)** by Rete Semi Rurali; Crop: Wheat; Product: Bread; Value chain region: Tuscany (Italy).
- Breeding program: Development of an organically bred, open pollinated (OP) variety, as potential example of **Organic Variety (OV)** bred by Kultursaat and commercialized by Bingenheimer Saatgut; Crop: Beetroot; Product: Beetroot juice; Value chain region: Germany.
- Breeding program: Dynamic management of agrobiodiversity program: In-situ selection/ conservation of a **local landrace / heirloom cultivar** (LR) by ProSpecieRara; Crop: onion; Product: onion; Value chain region: Romandie (Switzerland).

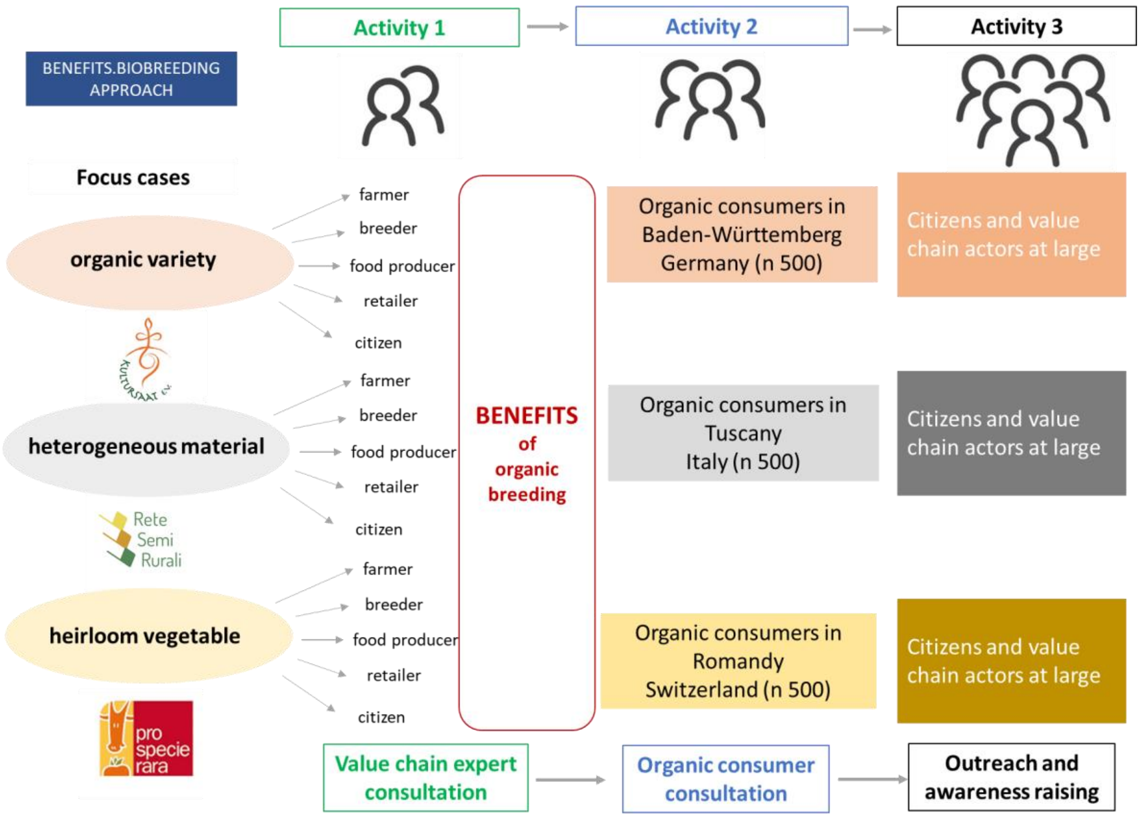
The two focus cases involving an organic variety and organic heterogeneous material were conducted in synergy with the LiveSeeding project, which provides co-funding to BENEFITS.BIOBREEDING. The focus case involving a local landrace/ heirloom cultivar was specifically added in benefits.biobreeding in order to cover the full span from agrobiodiversity heritage management to cultivar development in our assessment and communication of organic plant breeding benefits.

## 2. Background, Objectives and Scope

Benefits.biobreeding aims to take stock and raise awareness on the benefits of organic plant breeding for society and the environment using three concrete focus cases covering the two new cultivar types 'organic heterogeneous material (OHM)' and 'organic varieties (OV)' as well as 'local landraces/ heirloom cultivars (LR)'. This report presents the methodology and results of Activity 1 (value chain expert consultation), which is the first of a total of three activities (see Figure 1):

- Activity 1: Value chain expert consultation (focus of current report) (running from: 1.11.2023 to 31.10.2024);
- Activity 2: Organic consumer consultation (running from 1.11.2024 to 31.10.2025)
- Activity 3: Outreach and awareness raising to citizens and value chain actors (running from 1.11.2025 to 31.10.2026)

Figure 1: Benefits.Biobreeding – three focus cases and three activities.




Benefits.Biobreeding receives co-funding from the EU Horizon project LiveSeeding. The goal of LiveSeeding is to foster the growth of the organic sector and transition towards more sustainable local food systems. LiveSeeding aims to achieve this by delivering high quality organic seed of diverse cultivars adjusted to organic farming for a wide range of crops. By "adjusted to organic farming" it is meant that cultivars are 'work well' under organic conditions, for instance, they resistant to diseases and can be cropped without the use of synthetic pesticides and are genetically heterogeneous and therefore can adapt locally when grown for several years in the same environment.

As indicated in the EU Organic Regulation (2018/848), organic breeding activities shall be conducted under organic conditions and shall focus on the enhancement of genetic diversity, reliance on natural reproductive ability, as well as agronomic performance, disease resistance and adaptation to diverse local soil and climate conditions.

Moreover, organic breeding shall:

- contribute to the overall organic farming goal of preserving and enhancing biodiversity by increasing the number of cultivated species, supporting cropping systems diversification, developing new, diverse cultivars and actively preserving genetic resources (dynamic use of agrobiodiversity);
- develop locally adapted cultivars that satisfy specific needs of organic farmers, processors and consumers (which are poorly addressed by the conventional breeding sector);
- address the complexity of climate change by developing cultivars that are resilient against various abiotic and biotic stresses, stabilize yield and high quality, decrease the dependency on external inputs, thus reducing the use of agrochemicals, environmental contamination and greenhouse gas emissions;
- respect values and principles of the organic sector in terms of breeding methods alignment with organic farming principles defined by IFOAM Organics International and fair management of Intellectual Property Rights IPR with the rejection of patents and the promotion of "seeds as commons" concept[1]);
- ensure the integrity of organic products ("Organic right from the start!").

As identified in previous projects (e.g. Engagement.Biobreeding, RightSeeds, LIVESEED, DIVERSIFOOD, Solibam), the many benefits of organic breeding span the whole value chain/ food system. However, organic breeding today plays only a niche role and needs to be more strongly promoted.

There is an **undersupply of organic cultivars due to a lack of awareness among value chain actors**, including consumer-citizens, and the difficulty in promoting the public goods organic breeding provides (e.g. increase in agrobiodiversity, access to genetic resources). According to a consumer consultation in the project DIVINFOOD consumers are not able to make a connection between agrobiodiversity and the food they eat (Chiffoleau et al., 2024). Additional information relating to the positive impacts of

[1] Organic breeders, according to the type of cultivar developed (e.g. pure line, OP variety, population) and with the formal modality selected for the market delivery of the cultivar (e.g. UPOV regitration, adjusted OV registration, OHM notification) may use Plant Variety Protection (need to pass DUS criteria) or have the material free from IPR (e.g. in the case of OHM notification). Under no circumstances are patents allowed in organic breeding. In the case of cultivars with no IPR, OSS licence and OSSI pledge can be used (links: https://www.opensourceseeds.org/en/home , https://osseeds.org)

organic varieties on livelihoods and the environment is urgently needed to raise consumers' and other value chain actors' awareness about the benefits of organic breeding.

**The main objective of this study was to (1) identify and evaluate the benefits and costs of organic plant breeding and (2) propose communication strategies and narratives to increase consumer-citizens' awareness on the societal and environmental value of organic plant breeding.**

For (1) **the assessment of benefits and costs**, we selected three concrete focus cases among the organic plant breeding initiatives that are part of the LiveSeeding project (www.liveseeding.eu). They cover the two new cultivar types (i) Organic Heterogeneous Material (OHM) and (ii) Organic Varieties suitable for organic production (OV) listed in EU Organic Regulation (2018/848) as well as (iii) local landraces / heirloom cultivar. Each case study is based on a relevant organic selection/ breeding program and an established value chain. **For each case, we identified the benefits/ advantages as well as costs/ disadvantages as compared to (i) homogeneous lines and (ii & iii) F1-hybrids, respectively, based on the knowledge of experts and value chain actors and created a list of indicators and statements for further evaluation. For the OHM and OV cases, the list of indicators was evaluated by value chain actors.**

For (2) based on the results of this report a consumer-citizens targeted publication was produced to summarise and visualize these narratives/ messages which will be tested and validated by the multi-actors platform of the LiveSeeding Living Lab network.

The case-study approach is meaningful for two reasons: Benefits and costs are very cultivar specific. In addition, being as concrete as possible in communication with consumer-citizens raises the credibility and comprehensibility of the messages conveyed. At the same time, the benefits and costs identified only hold for the cases analysed, unless differently stated in this report.

For each focus case we describe the value chain and the specific approach followed to identify and evaluate the benefits and costs and present the results of the benefits and costs evaluation.

# 3. Benefits and costs evaluation

## 3.1 General approach and methodology

To evaluate the benefits and costs of organic plant breeding, we selected three concrete focus cases among the initiatives that are part of the LiveSeeding project, each including a relevant selection/ breeding program and an established value chain.

The main criteria for the selection of the initiatives and value chains were:

- Representation of organic breeding approaches (Organic Varieties/ Organic Heterogeneous Material/ Landraces) focusing on developing/ conserving adjusted and highly resilient cultivars, in different climate and cultural context;
- Crops with relatively high organic market share/ high percentage of area under organic cultivation covering both arable crops and vegetable species;

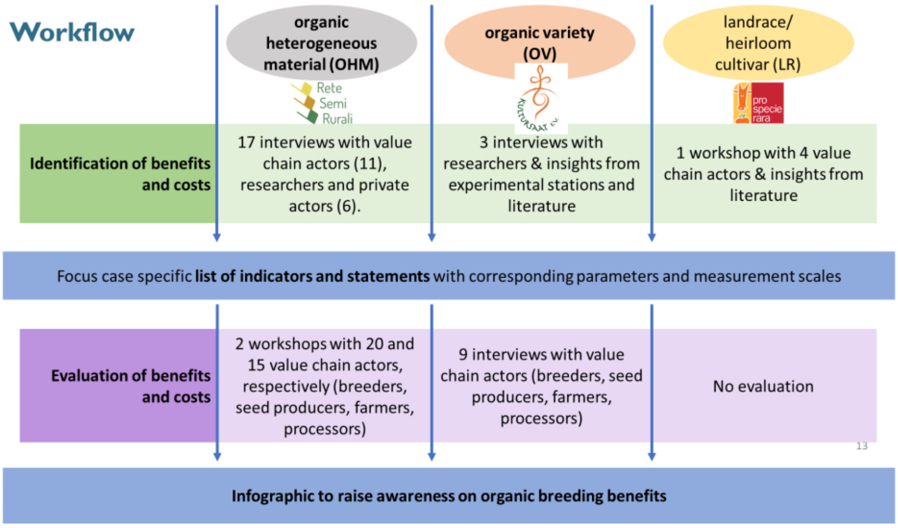
- A high effort of organic breeding on the selected crop that reached already to the market;
- Relatively high organic seed use and agronomic experience with organic seed use by farmers for the selected value chain;
- The existence of a well-established value chain and outreach to consumers.

The three focus cases are:

- Breeding program: Development of a Composite Cross Population (CCP), as a potential example of Organic Heterogeneous Material (OHM) by Rete Semi Rurali; Crop: Wheat; Product: Bread; Value chain region: Tuscany (Italy). – Subsequently referred to as the **OHM case.**
- Breeding program: Development of an organically bred, open pollinated (OP) variety, as potential example of Organic Variety (OV) bred by Kultursaat and commercialized by Bingenheimer Saatgut; Crop: Beetroot; Product: Beetroot juice; Value chain region: Germany. – Subsequently referred to as the **OV case**.
- Dynamic management of agrobiodiversity program: In-situ selection/ conservation of a local landrace / heirloom cultivar (LR) by ProSpecieRara; Crop: onion; Product: onion; Value chain region: Romandie (Switzerland). – Subsequently referred to as the **LR case**.

In all three focus cases, benefits and costs were identified through individual interviews (OHM and OV cases) and a workshop (LR case) with researchers and value chain experts, respectively. Value chain experts included breeders, seed producers, farmers, processors (if relevant), and consumers. Based on these results and literature a list of indicators and statements with related parameters and measurement scales was then created in order to quantify the benefits and costs identified. For the OHM and OV cases, the indicators and statements were then evaluated through a workshop (OHM case) and individual interviews (OV case) with value chain actors (breeders, seed producers, farmers, processors, and consumers), respectively, and corresponding results were validated based on insights from literature. For the LR case, indicators were not evaluated. Figure 2 shows the research design of the value chain expert consultation (Activity 1).

Figure 2: Methodological approach of activity 1 (value chain expert consultation)



As the three focus cases are quite diverse in nature (value chain length, number of value chain actors involved, geographical reach, etc.) and also differ with respect to available pre-existing data and literature, the methodological approach as well as the final list of indicators are case study specific.

Please note that in this report the terms 'benefits' and 'advantages' are used interchangeably. The same holds for 'costs' and 'disadvantages'.

### 3.1.1 Indicator development

Indicators were selected with the goal (1) to quantify the most important **economic**, **ecological**, and **social benefits** and **costs along the value chain** as proposed for systems-based breeding approach (Lammerts van Bueren et al., 2018), from breeding to processing and consumption and (2) to understand the collaboration and creation of value along the entire value chain of the two focus cases assessed.

A first selection of indicators was performed based on existing Multi-Criteria Assessment Frameworks (Bohanec et al., 2008; Iocola et al., 2020; Rodriguez et al., 2021). Indicators were then fine tuned using existing relevant literature and expert interviews.

Importantly, in the present study we aimed to assess benefits and costs that are both, of financial and non-financial nature:

> If a benefit or cost is of financial nature, the good or service that it relates to is valued on the commodity market and sold or bought at a specific market price (this e.g. holds for yield or seeds). Thus, in that case the benefit or cost can be expressed in monetary terms. If a benefit or cost is not of financial nature, the good or service that it relates to is not valued on the commodity market and therefore has no 'price tag' (this e.g. holds for on-field genetic diversity OR plant vigour). Thus, in that case the benefit or cost cannot be expressed in monetary terms.

Whereas for some benefits and costs it was quite straightforward to find suitable indicators and related parameters in the literature (e.g., marketable yield (= indicator) in tons/ha (= parameter) or quantity of seed used (= indicator) per ha (=parameter)), it was more difficult for others (e.g. on-field genetic diversity, plant vigour, or taste). In the latter case, we used 9-point-Likert scales for the assessment (instead of specific parameters).

Indicators were selected based on the following criteria (Iocola et al., 2020):

- Relevance (to assess economic, ecological, and social benefits in the respective value chain);
- Non-redundancy (no overlap of information);
- Scientific value (not exclusive – if possible indicators had to be calculated in well-founded technical and scientific terms);
- Feasibility (indicators had to be easily assessed by study participants).

In addition to indicators, we also used statements to capture participants' opinion on certain benefits and costs and assessed them using 9-point-Likert scales.

In the following subsections, the followed research approach, the identified benefits and costs, the list of indicators and statements, and the evaluation results are presented for each focus case individually. Each subsection starts with a description of the respective focus case.

### 3.1.2 Limitations of the general approach

The current study heavily relies on past experience which was collected using interviews, workshops, scientific literature and/ or reports from field trials or experiments conducted on experimental stations, where available. Thus, the evaluation of indicator results represents and shall be interpreted as rough estimates. In addition, where no past experience was readily available, indicators could not be evaluated and further field studies or experiments are required.

## 3.2 Case study 1: FURAT wheat population in Italy as example of potential Organic Heterogeneous Material (OHM)

### 3.2.1 Case study description

The breeding programme of the soft wheat population FURAT (*Triticum aestivum* L.) was initiated by Salvatore Ceccarelli and Stefania Grando at ICARDA (Aleppo, Syria). In the years 2007 to 2009, they started to apply in their work the concept of evolutionary plant breeding as best suiting in order to "manage agrobiodiversity in a flexible way" (Ceccarelli, 2020) in barley, durum and soft wheat. For the soft wheat, seeds of segregating populations (ca.2000 F2, F3, F4 derived from crosses conducted at ICARDA using ca. 200 different parental lines) were bulked to one Composite Cross Population (CCP). This soft wheat population was distributed to farmers in Syria, Morocco, Algeria and Jordan for participatory plant breeding (PPB).

From 2010 to 2014, in the scope of the EU project SOLIBAM (www.solibam.eu) with ICARDA as one project partner, the ICARDA barley, sort and durum wheat CCPs have been introduced to Italy, where they have been grown and further developed on two organic farms, one in Tuscany and one in Sicily, and gradually distributed to different regions of the country (Petitti, 2021). Rete Semi Rurali (RSR) notified these populations to the Ministry of Agriculture in 2016, as part of the temporary experiment on marketing of cereal populations (2014/150/EU) and is managing the seed certification and liaisons with CREA-DC (the Italian Seed certification division). The populations have been officially named "FURAT", which is the Arabic word for the Euphrates river of the Fertile Crescent, where these cereals were first domesticated, as a reminder of their origin (Ceccarelli, 2023; personal communication). Currently, two different populations originating from the FURAT soft wheat population are notified in Italy, *FURAT tenero Floriddia popolazione* and *FURAT tenero Li Rosi popolazione*. They have been grown since

2010 in Tuscany and Sicily, respectively, and have adapted to the location so much, that they evolved in two different sub-populations as described by Bocci et al. (2020). Rosario Floriddia and Giuseppe Li Rosi are two of the farmers that received the seed from Salvatore Ceccarelli in 2010. Their farms are the only seed multiplying companies registered to sell the seed of the FURAT soft wheat population. In 2022, *FURAT tenero Floriddia popolazione* was grown for seed production on 12.67 ha and *FURAT tenero Li Rosi popolazione* on 9.91 ha. In 2023, it is expected that they will be grown on 16.62 ha and 10 ha for seed production, respectively. The amount of ha for seed production of all notified populations in Italy accounts for 88.9 ha in 2023 (internal data from CREA-DC, 2023). It is important to note that, whilst the European Commission's temporary experiment on cereal population ended February 2021 (2018/15199/EU), the Italian Ministry of Agriculture issued in 2022 a decree allowing farmers and seed companies to continue the production and marketing of the populations already notified, until the provisions for OHM of the new organic regulation (EU 2018/848) and delegated acts (EU 2021/1189) are officially adopted and implemented.

To evaluate the benefits and costs of OHM cultivars at different levels of the value chain in Europe, we chose the organic wheat population *FURAT tenero Floriddia popolazione* as focus case (see

Figure 3 and Figure 4). FURAT is commercially cultivated in the region of Tuscany and used for bread, beer, and pasta, amongst other products. Benefits and costs were evaluated in relation to the use of organically multiplied uniform lines (= baseline) in the context of organic farming.

Whenever in the following chapters the population FURAT is mentioned, it refers to this particular cultivar. Rosario Floriddia is the organic farmer multiplying the seed of this population and his farm is registered as official seed multiplying company for this cultivar. In the region of Tuscany, there are several organic farmers, who bought seed from his company and are now growing the population. They are usually saving the seed on farm and managing the genetic diversity themselves. Most farmers are either processing and selling the products from FURAT on farm or working together with artisan food transformers close-by, often in a rural context. As a result, there is not one single large value chain, but there are several small, local ones. RSR is providing a network where they can exchange experiences and supports them with issues that cannot be solved by a single farmer or processor, such as adopting an open-source seed pledge for FURAT seed, creating a narrative for FURAT products' lables, or conducting research projects investigating FURAT and the corresponding value chains in a scientific way. There is an ongoing exchange between stakeholders of the FURAT value chains and the experts working at RSR, therefore stakeholders also have an influence on what is been put on the agenda of RSR.

Figure 3: “FURAT tenero Floriddia popolazione” field for organic seed production on the farm of Rosario Floriddia in Peccioli, Tuscany, Italy (Photo: Marlene Sander, June 2023).

Figure 4: Plants of “FURAT tenero Floriddia popolazione” in a field for organic seed production on the farm of Rosario Floriddia in Peccioli, Tuscany, Italy . Phenotypic differences between single plants within the cultivar can be clearly seen. (Photo: Marlene Sander, June 2023)

### 3.2.2 Case-specific methodology for the selection and evaluation of indicators

Literature about highly genetically diverse wheat populations and organic heterogeneous material (OHM) exists, nevertheless it mainly focuses on the agronomic aspects. This is the reason why a comprehensive, qualitative pre-study was necessary for the case study of OHM to identify the potential benefits and costs of OHM as compared to uniform lines. In this qualitative pre-study we interviewed a total of 17 experts, 11 of which are involved in the FURAT value chain as breeder, seed multiplier, farmer, or processor. These interviewees were recruited by Rete Semi Rurali (RSR). Many of the experts within the value chain are have multiple roles in the value chain, some even have their own value chain, meaning they are breeders, seed suppliers, farmers, processors and researchers at the same time. The other 6 interviewed experts are part of relevant research groups or companies from all over Europe working with OHM. To obtain a differentiated picture on OHM, these 6 experts were chosen to cover the entire spectrum of opinions about OHM, including some more critical voices. Table 1 lists the interviewed experts, including their profession and affiliation.

**Table 1: List of interviewed experts (indicated in the Table as "E"), including their profession and affiliation for the FURAT case.**

| ID | Profession | Association/ company |
|---|---|---|
| E1 | Breeder, researcher | Network for local varieties |
| E2 | Breeder, researcher | Network for local varieties |
| E3 | Researcher | Retired, former professor |
| E4 | Breeder, seed producer, farmer, processor, researcher | Own farm |
| E5 | Seed certifier | Italian seed certification authority |
| E6 | Seed producer | Seed company |
| E7 | Farmer, processor | Own farm |
| E8 | Farmer, processor | Own farm |
| E9 | Farmer, processor | Own farm |
| E10 | Processor (baker) | Own bakery |

| | | |
|---|---|---|
| E11 | Breeder, researcher | Retired, former professor |
| E12 | Researcher | University |
| E13 | Researcher | University |
| E14 | Breeder, researcher | Organic breeding company |
| E15 | Researcher | Research institute |
| E16 | Breeder | Retired, organic breeding company |
| E17 | Researcher | Authority |

The expert interviews were semi-structured and conducted based on the following guideline (see Table 2).

**Table 2: Interview guideline FURAT wheat case**

| Interview section | | Content |
|---|---|---|
| 1 | **Introduction** | Goal of Liveseeding<br><br>Fundamental research question of the current study: What are the benefits of using OHM cultivars? What are the conditions under which OHM performs the best? |
| 2 | **Profiling**<br><br>(Questions 1-8) | Profession<br><br>Institution/Company/Farm<br><br>Personal background in that field<br><br>Description of the associated value chain |
| 3 | **Stakeholders attitude**<br>(Questions 9-11) | Attitude of interview participant towards organic breeding and OHM<br><br>Traits that are considered to be important for wheat cultivars |
| 4 | **Experience with FURAT/ OHM cultivars**<br><br>(Questions 12-19) | • Breeding process<br>• Advantages and disadvantages<br>• Overall performance<br>• Ideas for improvement |
| 5 | **Opportunities and threats** | External factors that could influence the adoption of OHM cultivars (positive or negative influence) |

| | | |
|---|---|---|
| | (Questions 20-25) | |
| 6 | **Closure** | Next steps<br>Other factors that participants would want to mention |

The questionnaire was adapted for breeders, seed producers, farmers, processors, researchers and members of an authority. It is important to state that if a person had different professions, they were asked to answer the questions from the perspective of each profession individually. The complete questionnaire which was used for farmers can be found in the Annex 1.

In a second stage the identified benefits and costs of OHM were quantified, using FURAT as an example. This was done through a stakeholder workshop, which included breeders, seed multipliers, farmers, and processors (mainly millers and bakers) from the 'Cereali Resilienti 3.0' EIP-Agri Operative Group and network. Participants were recruited by Rete Semi Rurali. The workshop was held at the headquarters of Rete Semi Rurali in Scandicci on May 24th 2024. There were 8 breeders and seed producers, 7 farmers, and 5 processors. Importantly, some of the participants had also been interviewed as experts in the pre-study.

The workshop was structured described in Table 3.

**Table 3: Structure workshop FURAT indicator evaluation (24 May 2024)**

| FURAT value chain workshop sections |
|---|
| **Welcome and introduction (20min)** |
| **Group work (2 hours)**<br>• Overall introduction (10min)<br>• Exercise on the motivation to be part of the FURAT value chain (20 min)<br>• Evaluation of costs and benefits – "Is OHM wheat (Furat) a good alternative to other more homogeneous wheat cultivars (like pure lines or old varieties/ landraces) used in the network?" (90min)<br>  ○ Introduction (5 min)<br>  ○ Individual evaluation of indicators (25 min)<br>  ○ Selection of 5 indicators most difficult to evauluate and selection of 5 indicators most important (10 min)<br>  ○ Discussion of most difficult indicators (20 min)<br>  ○ Discussion of most important indicators (30 min) |
| **Plenary (45 min)**<br>• Presentation of results and discussion (45min) |

For the group work, participants were split into 3 groups: (i) breeders and seed multipliers; (ii) farmers; and (iii) processors. Each group evaluated only a subset of the total list of indicators:

- Group of breeders and seed producers: Indicators related to the breeding, seed production, and value chain/society levels;
- Group of farmers: Indicators related to the on-farm management, productivity, and value chain/society levels;
- Group of processors: Indicators related to the processing and value chain/society levels.

As a first warm-up exercise, participants were asked to complete three sentences with their own words:

- "I <u>enjoy</u> being part of the FURAT value chain as a breeder/ seed multiplier/ farmer/ processor/ consumer/ citizen, because…". (= intrinsic motivation)
- "I <u>benefit</u> from being part of the FURAT value chain as a breeder/ seed multiplier/ farmer/ processor/ consumer/ citizen, because…". (= extrinsic motivation)
- "OHM wheat like FURAT will become more relevant in the organic sector, because or if…". (= enablers)

The aim of the exercise was specified as follows: "The aim of this exercise is to identify the factors that motivate the use of OHM wheat, specifically FURAT".

In a second step, participants had about 25min time to individually evaluate the indicators provided to them on a sheet of paper. The aim of this exercise was specified as follows: "We developed a set of indicators to evaluate the costs and benefits of OHM wheat and want to apply it now to FURAT, to answer the question **'If OHM wheat (FURAT) is a good alternative to other more uniform wheat cultivars (pure lines, old varieties, landraces) used in the network**'."

After the individual evaluation, each participant received five red and five green sticky dots to mark the indicators they perceived most difficult (red dots) and the indicators they perceived most important (green dots) to answer the question: "**Is OHM a good alternative to more uniform wheat cultivars (pure lines, old varieties, landraces) used in the network?**" . The moderator then identified the indicators with the highest number of red and green sticky dots and tried to obtain a 'consensus value' for these indicators. After the group work, all participants gathered and each group facilitator presented the results of the group work, focusing on the evaluation of most difficult and most important indicators, answering the question if OHM wheat, and FURAT specifically, is a good alternative to other more homogeneous wheat cultivars used in the network. Due to the small number of processors, a second session with processors was organized by Rete Semi Rurali one week later on June 7th in Peccioli (Italy) with actors from the Cereali Resilienti Network. The session was attended by a total of 15 participants.

In the results section we will use the term 'experts' to refer to the participants of the expert interviews (qualitative pre-study) and the term 'stakeholders' to refer to the participants of the workshop.

### 3.2.3 Results of the explorative expert interviews

The expert interviews resulted in a list of potential and/or perceived benefits and costs of using OHM cultivars in wheat cultivation (see Table 4 and Table 5).

**Table 4: Potential (perceived) benefits of using OHM cultivars in wheat cultivation.**

| Type | Stakeholder | Potential benefits of OHM cultivars as of expert interviews |
|---|---|---|
| Social/ well-being | Breeders | Breeding activities strongly embeded in the value chain |
| | Farmers | Seed sovereignty (possibility to produce own seed), farmers are owners of seed |
| | | Independency from the global seed and wheat market |
| | | Suitable approach for farmer and community involvement in development and mainataince of the cultivar (Participatory Plant Breeding) |
| | | Community building, connecting, stronger collaboration along the value chain |
| | | Unique seed and possibility to create a "farm cultivar" |
| | | Collaborative innovation (including social innovation, beyond simple technical innovation) |
| | Processors/ consumers | Very good taste |
| | | Good nutritional value |
| | | Digestibility of products (bread) |
| | Society | Diversity of diets and taste |
| | | Seed as common good, no patents, no IPR |
| Economic | Breeders | Lower breeding costs |
| | | Quick improvement through adaptation |
| | Farmers | Yield stability |
| | | Quality stability |
| | | Good disease resistance |
| | | Adaptation to the growing location over the years |
| | | Comparable weed competitive ability |
| | | Higher nutrient use efficiency and water use efficiency |
| | | Baking quality for artisanal baking |
| | | Gluten quality for artisanal baking |

| | | |
|---|---|---|
| | | Long shelf life of products (bread) |
| Ecological | Farmers | Genetic diversity within the cultivar |
| | | Buffer effect against external stress, e.g. extreme climatic situations |
| | | Facilitate organic cereal cultivation without the use of syntetic fertilisers and pesticides |
| | | Positive influence on soil health |
| | Society | Dynamic management of genetic diversity thorugh cultivation and use |
| | | A support to adaptation of agriculture to climate change (Higher genetic diversity and therefore better adaptability) |
| | | No GMO and NGTs |
| | | Seeds as common good |
| | | Cultivar is bred in the same region, where it is cultivated |

**Table 5: Potential (perceived) costs of using OHM cultivars in wheat cultivation.**

| Type | Stakeholder | Potential benefits of OHM cultivars as of expert interviews |
|---|---|---|
| Social/ well-being | Breeders | Traceability management |
| | Farmers | High responsibility |
| | | Requires high effort from stakeholders |
| | | Very knowledge intensive for stakeholders |
| Economic | Farmers | Specific value chain is needed |
| | | Risk of losing the adapted seed ( if there is no back up storage) |
| | | Populations are usually not made for maximized performance (concerning yield and quality) |
| | | Seedborne disease management |
| | | Seed conservation and maintenance |
| | | Seed supply and limited choice of populations on the market |

| | | |
|---|---|---|
| Ecological | Farmers | Risk of losing genetic diversity within the population because of strong adaptation to single location |

### 3.2.4 List of indicators and statements

The list of indicators and statements which was developed based on the findings from the expert interviews and assessed in a participatory workshop with value chain actors can be found in Annex 1.

For the assessment of indicators, we either used a specific parameter – if available and feasible for participants to assess – or a 9-point-Likert scale. If it was considered feasible for participants to assess FURAT relative to more uniform lines, a relative scale was used, if not, an absolute scale was used:

- ***Scale to compare Furat to a uniform line (relative scale):*** 1 = much lower than a pure line; 3 = lower than a pure line; 5 = the same; 7 = higher than a pure line; 9 = much higher than a pure line
- ***Scale to rate Furat (absolute scale):*** 1 = very bad, 3 = bad, 5 = average, 7 = good, 9 = very good

For the assessment of statements, the following 9-point-Likert scale was used:

- ***Scale of agreement to a specific statement:*** 1 = do not agree at all, 3 = do not agree, 5 = average, 7 = agree, 9 = fully agree, 88 = it depends, 99 = don't know

Initially it was planned to use a modern wheat variety as a comparison. However, during the interviews and the definitions of questions and indicators, it became clear that modern varieties were totally unsuitable for cultivation in the marginal/hilly organic environments of the majority of the farms participating in the workshops. Modern wheat varieties are characterized by a reduced plant height, which gets even shorter without chemical fertilizers, rendering their weed suppression ability almost non-existent under organic conditions. Therefore, participants were asked to think, as a term of comparison, to an old or local variety of tall size, that they would normally grow (e.g. Verna). Such varieties have low to moderate yields but exhibit good quality traits (flavour, gluten type) and are particularly appreciated by consumers. For this reason, a comparison between OHM and cutting-edge modern varieties could not be established here and would require a different type of study or more complex market analysis.

### 3.2.5 Evaluation of indicators and statements

We first present the financial benefits and costs that arise in the FURAT value chain and then list the advantages and disadvantages of OHM as compared to uniform lines in the context of organic farming which were identified in the interviews with experts and value chain actors.

#### 3.2.5.1 Financial benefits and costs in the FURAT value chain

The financial benefits and costs presented in Table 6, apply for the following scenario: An organic, local value chain including all stakeholders: Breeder, seed producer, farmer, and processor of an OHM cultivar, e.g. FURAT. The time span is one year.

**Table 6: Financial benefits and costs in the bread wheat FURAT value chain in Toscany (Italy) assessed in 2024**

| OHM | | | |
|---|---|---|---|
| **Indicator** | **Parameter** | **Min** | **Max** |
| **Breeding** | | | |
| Breeding duration | years | 5 | 10 |
| Breeding costs | EUR/variety | Much lower than for pure lines[2] | |
| **Seed production** | | | |
| Certified seed needed per ha | dT/ha | 1.3 | 3 |
| Certified seed produced per ha | dT/ha | 20 | 40 |
| Average amount of certified OHM seed sold in the last 5 years | dT/year | 60 | 300 |
| Average demand of certified OHM seed in the last 5 years | dT/year | 50 | 300 |
| Selling price for certified OHM seed | €/dT | 140 | 180 |
| Income (seed sales) | €/year | 8’400 | 54’000 |
| Area needed to store seed | $m^2$/dT | 0.2 | 0.5 |
| Costs to store seed | €/dT | 0.015 | 3.00 |

[2] A standard quantification of the breeding cost for the development of an OHM is not possible because it depends very much on the breeding approach used (CCP, dynamic mix, farmer’s selection), the number of parentals and the access to the start material. In particular for FURAT the possibility to access in the context of a research project the segregating material from crossings done by ICARDA and provided for free for the initiation of the population cannot be quantified.

| | | | |
|---|---|---|---|
| Labor input for seed cleaning | h/dT | 0.10 | 0.25 |
| **Cultivation** | | | |
| Amount of seed needed for wheat cultivation | dT/ha | 1.5 | 3 |
| Amount of seed saved on farm | dT/year | 4 | 60 |
| Yield potential | dT/ha | 25 | 42 |
| Yield compared to the location's yield potential[3] over the last 5 years | % | 75 | 120 |
| Yield range over the last 5 years | dT/ha | 10 | 35 |
| Yield suitable for human consumption in the last 5 years | % | 70 | 100 |
| Grain: Selling price | €/kg | 0.60 | 0.75 |
| Income (grain sales) | €/ha | 420 (70%)/ 600 (100%) | 1'225 (70%)/ 2'625 (100%) |
| **Processing** | | | |
| Flour: selling price | €/kg | 1.40 | 3.00 |
| Bread: selling price | €/kg | 5.00 | 8.90 |

#### 3.2.5.2 Advantages and disadvantages of using OHM cultivars in wheat production

**Breeding and seed production level**

Advantage 1: The use of OHM cultivars **strengthens the cooperation along the value chain**, which is an advantage that was frequently mentioned during the expert interviews and on which most participants of the workshop agreed. Specifically for breeders, it is a way to actively embed their activities into the value chain and work collaboratively with the seed producers and farmers. Many breeders that are working with OHM cultivars see that as a major positive aspect, which emerged also from the listed intrinsic motivations to be part of FURAT value chain during the workshop.

[3] Yield potential refers to the yield under optimal growing conditions.

**Advantage 2:** The development of **OHM allows farmers to be directly involved in breeding** (development of OHM is a suitable approach for participatory plant breeding). Additionally, **OHM breeding is very flexible and allows to use different strategies** (composite crosses, dynamic mixtures, farmers' selections [4]) according to resource availability and type of actors involved as breeders/developers.

Concerning the breeding of OHM cultivars using a Composite Cross approach (to which FURAT belongs), two main philosophies emerged from the workshop. The first one aims for as much genetic diversity within one population as possible. This approach was followed when breeding the population FURAT by pooling together a large genetic base from the segregating material from a large number of crossings by ICARDA (see case study description). The proponents of this philosophy support the idea that natural selection will favour the best suiting plants for the location where the cultivar is grown and that the diversity only has to be managed to a certain extent in order to support natural selection. The proponents of the second philosophy think that it is more efficient to select the parental lines carefully in order to include specific traits in the population. They argue that natural selection favours plants with the hightest fitness (i.e. producing the highest number of seeds), but is blind towards quality traits, which are crucial for a successful value chain. Therefore, these traits have to be controlled by breeders from the eary stages of selection.

The stakeholders that took part in the workshop confirmed that breeding an OHM cultivar can actively involve selection by breeders and farmers beside relying on natural selection in different environments.

The balance between pre-breeding efforts, participatory breeding activities and evolutionary breeding approach can be flexibly adjusted according to resources and facilities available. The OHM development concept allows for the possibility for very cheap approaches fully farmers-led in case of limited resources and more complex approaches using at best pre-breeding efforts when collaborations and more resources can be mobilised.

**Advantage 3:** The development and use of OHM allows for the setting up of **new, farmer-led seed production micro-enterprises** that allow to **diversify the seed offer for the farmers**. This advantage emerged strongly in the discussion about intrinsic and extrinsic motivations for being part of the FURAT value chain. It is especially important in the context of rural areas, where building up local, small value chains is often the only way to create a source of income, to improve the overall economy of the region and prevent the abandonment of rural areas.

**Disadvantage 1:** From the perspective of the conventional plant breeding system, one challenge of breeding OHM cultivars and providing their seed is the **lack of funding for organic breeding, including dedicated financing models for OHM develpment, since intellectual property rights do not apply to this type of cultivar.** What is a **clear advantage for farmers** (the possibility to produce farmer saved seed independent from

[4] For background information on OHM development approaches see Costanzo et al. (2019)

the species and the amount, and the possibility to be directly involved in breeding, see Advantage 2 and Advantage 4) **and society** (preservation of seeds as common good) can pose a challenge for breeders and multipliers as their work has to be financed and recognized in a different way. The experts support the critical view on the conventional system of financing breeding programmes, however they have had to put effort in building a new system which is independent from IPRs and royalties. This is the reason why it is important to embed the breeding activities in the value chain, as described in Advantage 1. In fact, discussions during the workshop showed that the **breeders and seed producers already working with OHM cultivars mostly agreed on the absence of IPRs to be a positive aspect**, nevertheless during the expert interviews the issue was raised as a challenge for breeders being used to the conventional breeding system.

Disadvantage 2: Until now, there are only few seed producers for OHM seed and the work of breeders and multipliers is based on trust. As discussions during the workshop showed, stakeholders doubt the ongoing of this trustful relationship once the value chains of populations get bigger and more stakeholders are involved. In relation to that, they pointed out the risk of misappropriation of seed of populations and difficulties regarding quality ensurance, which can harm the reputation of OHM or of breeding companies. If the number of breeders and seed producers increases, **traceability will be an issue that needs to be addressed** to avoid that concerns about seed misappropriation and loss of quality will materialize. For instance, the current basic notification system for OHM needs to be improved and actually implemented in Italy. The organic regulation in which OHM is specifically allowed, came into force in January 2022, but in many European countries a national procedure for the notification of OHM cultivars is lacking[5].

### Farm level

Advantage 4: One major advantage of using OHM cultivars for farmers is ***seed sovereignty*****. Saving seed from growing season to growing season on farm in order to adapt the cultivar to their specific location is one of the main strengths of OHM**, according to the expert interviews. This was confirmed by the workshop participants. The farmers agreed upon the fact that the absence of IPR is an advantage: from 7 workshop participants, 5 answered with a score of 7 or 9, one with a 5 and one said it depends. Within the group of breeders and seed producers, there were some critical views. 5 of them answered with a score of 7 and 9, meaning they agree on the absence being an advantage, one with a score of 5 (no opinion in one of the irections) and one

[5] An inventory of all notified organic heterogeneous materials (OHM) in the EU is available online https://www.geves.fr/variety-seed-expertise/organic-agriculture/organic-heterogeneous-material/ and candidate OHM for case studies and field trials are listed and regularly updated by LiveSeeding WP2 project team.
Project partners in several EU Member States have been involved in the implementation of the notification procedure as well as the risk based post-marketing seed quality controls for OHM in their respective countries. Liveseeding WP3 team is developing OHMTrack a digital traceability tool, at the moment in testing phase by the partners (https://ohmtrack.aedit.it)

gave a score of 3, meaning to disagree. However, it should also be mentioned that for small farmers, IPR does not apply for farm-saved cereal seed (1768/95/EU Art. 7). Therefore, for farmers falling under this threshold this advantage is more perceived than real for the specific case of wheat and small scale farms. The opinion expressed can also be interpreted as a general agreement towards the advantage for farmers of IPR free material which allow for farm saved seeds independently of crop and amount.

**Advantage 5:** Another advantage of using OHM cultivars from the perspective of farmers is their **independence from the global market**. A total of 4 out of 6 farmers perceived themselves to be very independent of the global wheat market, incl. big seed companies, when using OHM cultivars. One perceived the independence to be high, and one more farmer perceived to be not independent at all. Here it should be noted that the independence from the global market, being wheat a commodity, can be intended both from the global seed market and the grain market (price and standard value chains). The possibility to sell and use the grain in value chains independent from the global market arised as very important in the discussions related to the extrinsic motivations to be part of FURAT value chain. This is because it is very difficult to value the overall sustainability commitment of the farmers involved in FURAT cultivation within the frame of the global market (e.g. if those farmers would sell their produce as commodity).

What comes with the independence is the responsibility. It was reported by the experts, that it can be ***challenging for farmers to be responsible for the maintenance*** of the cultivar and the seed production on top of the standard duties of farming. Many farmers also process the raw material on-farm, which comes with even more responsibility and workload. During the workshop, 5 out of 6 farmers stated to have a higher workload with cultivating OHM cultivars, one farmer perceived the workload with OHM cultivars as average for cereal farming.

**Advantage 6:** The responsibility goes hand in hand with the ***required knowledge***, a further point which was mentioned in the expert interviews. In the workshop, 4 out of 7 farmers agreed that more knowledge is needed when cultivating OHM cultivars compared to pure lines, 3 said that the required knowledge is average. The possibility to gain that knowledge and therefore take over responsibility is seen as a positive factor by the actors along the value chain. However, this can also be a bottleneck for upscaling OHM, which has to be taken into account when aiming to expand the use of OHM.

**Advantage 7:** The benefit which was mentioned the most during the expert interviews, was the ***yield stability over time***. According to the experts, yield stability is important for farmers in order to have a high level of certainty about their harvest and therefore their income. Nevertheless, the yields recorded over the last 5 years by the workshop participants could not confirm this perceived yield stability. The reported yields ranged from a minimum of 10 dT/ha to a maximum of 35 dT/ha. During the discussion, farmers agreed on these values, and set a realistic average value of 28 dT/ha. It has to be taken into consideration that many farms have started growing FURAT from a relatively short time, and they are often in marginal lands which are not best suited for high-yield wheat production. Considering these conditions, the yield values reported are quite acceptable, even though they might seem lower than the the Tuscany official average yields of 34,9 (2018), 34,7 (2019), 38,2 (2020) and 35,2 (2021) dT/h. Unfortunately these data refer to conventional soft wheat production and no official statistics is available for organic production. An estimation based on expert-knowledge within RSR team would suggest a range from 20-25dT/ha in marginal lands to 35-40dT/ha for fertile lands under organic growing conditions.

The two workshop participants that are both cultivating the population and producing certified seeds, reported that FURAT started with lower yield in their farm and that the yield increased over the years, maintaining a high stability from year to year. In their farms, a higher stability over time greater than more uniform cultivars (usually landraces in their case) was observed. However, the high inter-annual climatic variability and the extreme drought of 2023 make it difficult to present yield stability analysis without correlations to meteorological data, which was not possible in this study. Several expert interview participants pointed out, that also pure lines, organically bred or not, can be bred for stability over different regions (wide adaptation). This consideration shows how the approach on dealing with Genotype X Environment interaction can be different, with "conventional" breeding focusing rather on wide adaptation (GxE minimization) and OHM breeding trying to make use of GxE interaction aiming at local adaptation and stability across time, within each locally-adapted (sub)population.

Additionally, when growing populations, there seems to be at least a minimum yield that a farmer can count on, especially when cultivating in marginal areas or in case of extreme stressors (see **Advantage 8**).

**Advantage 8:** Due to populations' genetic diversity, some plants within a population are always more adapted to specific conditions. Thus, each year some plants can produce more efficiently within the conditions of that particular year, ensuring that even during extreme conditions there can be a minimum yield. According to the experts, populations are also described to have a **buffering effect against extreme conditions**, that are getting more frequent and severe due to climate change. This resilience to extreme climatic conditions can be considered similar to a risk insurance for the farmer. The workshop participants confirmed that the buffering effect is much higher for OHM than for pure lines. On a scale from 1-9 (1=buffering effect much lower than of a pure line to 9=buffering effect much higher than of a pure line) 5 of 6 farmers and all 8 breeders gave a score of 7 or 9. On top of that, 3 farmers and 6 breeders/seed producers evaluated this indicator to be particularly important. The discussion amongst the farmers resulted in an overall score of 7 for the buffering effect. This is described to be higher than for pure lines, although we couldn't assess exact quantification on that.

**Advantage 9:** Whereas **disease resistance** was mentioned in the expert interviews to be an advantage of OHM cultivars in general, workshop participants were divided in this respect when looking at the specific case of FURAT: Some indicated that the disease resistance is worse than in a pure line, some others experienced a better disease resistance of OHM cultivars compared to pure lines. Overall, this indicator was ranked to be important by the interview participants. In our evaluation activity it was not possible to discuss in detail the resistance to each major common wheat disease. Nevertheless, good seed cleaning, conservation and management of the population was mentioned to be crucial to avoid seedborne diseases, which are of highest importance in organic farming because fungicide seed coating is not used.

**Advantages 10 and 11:** Both **nutrient use efficiency and water use efficiency** were perceived as a positive characteristic in the expert interviews and were rated by workshop participants to be good, with 4 of 6 farmers answering with a score of 7 (=good) and two farmers rating the nutrient use efficiency as average. The common value the farmers agreed on for both, nutrient use efficiency and and water use efficiency, was a score of 7.

**Advantage 12:** Another positive factor mentioned was the **positive influence on the soil**, that can come from the genetic diversity of plants within populations. According to one expert, the genetic diversity of populations has an influence on the diversity of microorganisms in the soil, which can relate to a better soil quality. Influence on the soil was not assessed in this workshop but plant-soil microbiome interactions are currently being studied in some of the farmers' field by the TRIBIOME (www.tribiome.eu) project.

**Advantage 13:** The **local adaptation** is one major benefit of OHM and can be seen as one of the most important arguments to grow an OHM cultivar instead of a more uniform cultivar. The ability of populations to evolve and adapt to the location where they are grown, was described in several expert interviews. The time needed for the adaptation cannot be defined easily, it depends on the environment and the level of natural selection connected to the geographical area and the growing conditions. The more extreme/stressful they are, the faster the adaptation is proceeding. According to experts, this is the case for both populations that are bred for the highest possible genetic diversity and populations that are bred for specific traits. The process of specific adaptation can lead to a quick improvement of the agronomic performance of the cultivar, without the necessity of a breeding programme for that particular location/environment. In the workshop, 5 of 6 farmers rated the local adaption to be higher than for pure lines, one said it is equal. The commonly agreed score was 7. 7 out of 8 breeders/seed producers rated the local adaptation with a 9, meaning much higher than for pure lines, one breeder/seed producer gave a score of 7, meaning still higher than a pure line. Even though the local adaptation process tends to reduce the level of genetic diversity within the cultivar in a particular farm, the overall diversity of the population is mantained when considering all the farms that use an OHM cultivar as part of the same system.

**Advantage 14 and 15:** As important as yield and yield stability is **quality for human consumption, and with it quality stability of the grain**. Usually, reaching the desired quality is a big challenge in organic cereal farming. Concerning populations, there seems to be divergent opinions: some of the experts reported a lack of quality stability, whilst others mentioned the quality and its stability as a positive factor. One expert even talked about a declining quality over the years. Consequently, one expert who is a researcher suggested to study the traits influencing the grain quality of wheat populations, in order to find strategies and practices to maintain these traits over time. From the perception of some experts, the stability of quality should be considered an advantage only if the population was bred for this trait. The ratings from the workshop participants for typical measures for quality as gluten content and protein content differed as well (between 1 = very low compared to a pure line and 7 = high compared to a pure line for the protein content and gluten content of OHM grain), reflecting the heterogeneous experience with quality of OHM cultivars. The value that the participants agreed on during the discussion was 7 for both measures.

Here it should be considered that the evaluation of quality can change according to the interpretation of what "quality" means, with possible differences between quality standards (e.g. gluten typology and quantity) necessary for "conventional" value chains (e.g. industrial scale bread production) and "independent/alternative" ones (e.g. type of gluten that can be considered satisfying in artisal bread making). The quality stability was not assessed during the workshop.

**Disadvantage 5:** The **handling of OHM cultivars on-farm** may be challenging for farmers. In some seasons / regions drying the grain before storage might be needed compared to a pure line, because of the genetic diversity not all plants are dry enough at the moment of harvest. This disadvantage was discussed in the workshop rather as potential risk than because of an actual problem in the cultivation of FURAT. And it was mentioned more specifically in te context of seed production.

On top of that, the saving of seed on farm can be a challenge and can result in seed with a lower quality than certified seed according to the experts and workshop participants.

**Disadvantage 6:** The interviewed experts stated the main challenge when growing populations is the **seed storage, seed purity and maintenance of OHM**. This includes keeping the seed free from seedborne diseases and contamination from other species, in the case of bread wheat mainly from durum wheat or barley, as well as storing the seed in a way that it is protected from other factors harming the seed (such as mold). In order to prevent the seed from an infection with diseases, a storage with the best conditions for seed storing is needed, including a dry and cool room which is protected from external influences. The two main seedborne diseases are smut and common bunt. Additionally, the maintenance of seed is important and requires a lot of knowledge. The cleaning often must be done by hand in case of small lots to eliminate the seed of different species, whilst keeping the diversity of seeds (e.g. varying sizes) within the population. The more common strategy is conducting roughing in the seed production field, where plants from different cereal species are removed. If the seed production and maintenance breeding does not work well, the risk of losing the adapted seed increases. When there is a year with extreme weather events, it can happen that the seed on the field is lost. For this purpose, it would be optimal to always store a part of the seed from the previous year as a safety backup, so that the adaptation that has occurred over years is not completely lost.

**Advantage 16:** The **weed competitive ability of populations** was mentioned by experts as an agronomic advantage as well. *FURAT Floriddia popolazione* is a relatively tall cultivar, with different plant height layers in the crop stand. Because of this, it is assumed by the experts to have a similar weed suppressive ability as of a tall landrace but a better lodging resistance because of the different layers. What was observed in the field by actors working with populations and pure lines, was that OHM cultivars are strong in the competition against weeds. However, weed competitive ability was not assessed in the workshop.

**Disadvantages 7:** Among the agronomic disadvantages that were mentioned in the interviews, one related to the **occurrence of lodging**. For *FURAT Floriddia popolazione* the plants are taller than the plants of modern pure lines. If lodging is higher compared to modern varieties, as explained in some interviews, this can in fact be the opposite compared to tall landraces, which are often the actual alternative choice by the farmers of the FURAT value chain. Due to the different layers of plant height within OHM cultivars, the plants can support and therefore prevent each other from lodging, as explained by another expert.

Additionally, lodging risk should be always considered together with weed competitive ability potential in the context of organic farming. The minimization of the trade off between weed competitive ability (**Advantage 16**) and lodging (**Disadvantage 7**) should be leading the cultivar choice by organic cereal farmers.

**Disadvantages 8:** The **risk to lose the genetic diversity of the population** over the years due to local adaptation and seed cleaning was mentioned. To prevent this, farmers are supposed to manage the seed in a way that genetic diversity is added whenever it shows the tendency to disappear. In the workshop, the breeders and seed producers group discussed in detail this aspect. Opinions were divergent if any measure should take place at seed cleaning level to avoid to loose diversity in the population.

One of the breeders mentioned that seed quality should be highest priority, so diseased/shrunken seeds should be eliminated even if there is risks to eliminate very small healthy seeds and their associated genotypes. One breeder mentioned that optical sorting machines should be used to get rid of weed seeds and diseased/discoloured wheat seeds, even if it can be difficult to deal with the different colours of the FURAT grain seeds. According to this breeder, the genetic diversity of the population is maintained at network level. All the seed-lots in the different farms together maintain the genetic base of the population, but it is normal that in single farms (for environmental and technical issues) there is shift / selection. **This could also be interpreted as an Advantage of collaborative responsibility in genetic resources diversity management.**

### Processing level

**Advantage 18:** The quality itself plays a major role in cereal growing. For bread wheat, the baking quality is most important. The baking quality of products from FURAT was described as good by experts. They supported this opinion on the baking quality of

OHM cultivars in general. One important part of the baking quality is the amount of gluten and the gluten quality. According to the workshop participants, the expected gluten content in FURAT flour is rather the same or lower than in the more uniform cultivars that farmers in the network would actually grow in alternative to the OHM.

Another important indicator for the baking quality of wheat is the protein content. The workshop participants expected the protein content in FURAT flour to be average, with some processors evaluating it to be higher and some other lower than the more uniform cultivars that would be cultivated by the farmers in the network.

Advantage 19: Another aspect related to the quality is the **nutritional value of the products as a whole**. Nutritional value is describing the composition of nutrients which can be rather fitting the human bodies need or not, and therefore can influence human health. Several interview participants specified the positive nutrient composition and therefore a good nutritional value as a benefit of FURAT products. No data could be evaluated for the nutritional value during the workshop.

Advantage 20: The **taste of OHM products was described to be very good and more flavourful** than the taste of products from pure lines. The taste also seems to differ from the taste of products from landraces and old varieties. The processors explained that it was an important point, since the customers remember the good taste and stick to OHM bread for that reason. The vast majority of 24 workshop participants (farmers and processors) confirmed that impression by rating the taste to be great. Only 2 processors evaluated the taste to be average or not good. The consensus amongst the workshop participants was a score of 9 for the taste as well.

Advantage 21: On top of that, **bread** from FURAT seems to have a **long shelf life**. The individual answers of the participants of the workshop were very diverse. They indicated a shelf life between 3 and 10 days. They agreed on an average of 5 to 7 days, when discussing the question in the group. In comparison, according to one interview participant, the typical bread from industrial production can only be stored for one day. However, this difference might also derive from the processing method instead of the cultivar used as raw material.

Advantage 22: Although FURAT is a bread wheat cultivar, to a certain extent it is also suitable for making pasta or other products like beer, according to the interviewed experts, pointing out a possible advantage in terms of **food products diversification**. Apparently, the diversity within the cultivar results in the grain being diverse as well and therefore including a part of the grains that have similar qualities to durum wheat (e.g. vitreous endosperm). The majority of processors who took part in the workshop agreed on this aspect, although two processors claimed that it was more suitable for beer than for pasta. The processors also reached a group consensus that FURAT is very suitable for beer and rather not suitable for pasta.

#### 3.2.6 Discussion

A number of field trials and projects including population/OHM wheat cultivars have been conducted in Europe, which help to back-up the perceived advantages and disadvantages emerged from the expert interviews and the evaluation in the workshop with *FURAT tenero Floriddia popolazione* value chain stakeholders.

**Genetic resources on farm, seeds as common good and related IPR governance and financing models debate**

Conservation of genetic diversity directly embedded in normal farming activities (through the cultivation of OHM) and collaborative innovation (including social innovation, beyond simple technical innovation) emerged as key benefits in the FURAT case. This allows the mainstream separation of the seed system from the food system to be reconciled through the development of connected, though independent, value chains around OHM. Working in a network with the facilitation of RSR allowed the FURAT value chain actors to create a common open-source seed pledge for FURAT seed and a narrative for FURAT products' lables.

Independency and participation were perceived also the as positive aspects by farmers involved in the INSUSFAR project in Germany (Burwitz, 2019). In line with the experts of FURAT, those farmers mentioned as well as the possibility to identify themselves with populations and the fact that they fight against seed monopolies.

Breeders involved in INSUSFAR saw OHM as a good possibility to contribute to the preservation and development of genetic resources for breeding and society as positive factors, but also saw, financing OHM breeding programmes, laws and how to implement them as challenges (Burwitz, 2019). These finding are in line with the opinions of the participants of the interview and workshop participants in the FURAT study. The importance of collective action within networks such as the one around FURAT was also highlighted in a study by Mazé et al. (2021) looking at analytical and theoretical foundations of the study of knowledge commons, connected with agrarian commons such as seed. The thought of a network, with sharing seed as well as knowledge and thus being mostly independent from the world market was mentioned as major motivation for the stakeholders of the value chain around FURAT.

The fact that, from January 2022, OHM can be officially marketed on the basis of a notification and without PVP, led to a regular discussion in the expert interviews and the stakeholder workshop about IPR, in particular PVP and related royalties for seed production in the financing of organic breeding programmes, even though this is a relevant issue not only for OHM but for organic plant breeding in general.

While the european organic breeding sector is clearly against the use of patents because it blocks the use of genetic material for futher breeding as well as for free access to farmers and society, the discussion about Plant Variety Protection is multifaceted. Some interviewed experts and a minority of breeders taking part in the workshop expressed their perception of the absence of IPRs and royalties in OHM breeding to be a disadvantage for them. Royalties are sometimes used in the organic breeding sector, but are discussed within the same (Kotschi & Wirz, 2015). They usually only make up for around 10% of the financing of organic breeding (Kotschi et al., 2022), making clear that this perceived disadvantage doesn't necessarily have to be a barrier for the uptake of the use of OHM cultivars. Other strategies that are currently used to finance organic plant breeding programmes are public funding, private funding through foundations, open-source seed licences or pledges, value chain collaborations, and levies (Kotschi & Wirz, 2015; Lazzaro et al., 2023). The goal is an independent organic breeding sector in order to provide enough seeds of  cultivars bred in organic farming until the derogations are going to phase out in 2036. FURAT value chain stakeholders are engaged in contributing to this aim as the development and use of OHM allows for the setting up of new, farmer-led seed production micro-enterprices that allow to diversify the organic seed offer.

#### Yield stability and resilience under stressful environmental conditions

One advantage very frequently mentioned during the expert interviews is the stability in yield and quality of wheat populations over time, within a growing site once adaptation took place.

The perceived benefit of yield stability over time in organic conditions is consistent with the findings of Bocci et al. (2020). The results of the study comparing populations, landraces, mixtures and modern varieties under organic conditions in Italy concluded that the heterogeneous populations yielded the same or better than the modern and more uniform cultivars. In addition, farmers' selection can help to further improve the performance of heterogeneous populations (Bocci et al., 2020). The authors conclude "that evolutionary populations are able to gradually evolve, adapting to each environment in which their seed is multiplied, reaching high and stable yield levels thus ensuring income to farmers, both as seed and as grain" (Bocci et al., 2020, p. 1).

Although many interview participants mentioned yield stability as a particular benefit of OHM cultivars in accordance with the cited study results, the values given by the farmers in the workshop could not confirm that benefit. This might be because many farmers are not very experienced yet with growing OHM, and the cultivar could not adapt yet to the growing locations. On top of that, many of the participating farmers are cultivating FURAT in marginal areas, usually not particularly suitable for wheat production. Furthermore, the high inter-annual climatic variability and the extreme droughts that hit at different levels, different Italian regions over the past 3-4 years, make it difficult to present yield stability analysis without thourough correlations with meteorological data. The combination of these factors probably let to the rather big range of yield mentioned in the results part.

A study by Vollenweider et al. (2020) examined the stability of yield and baking quality parameters of organic heterogeneous wheat populations in Germany and Switzerland, including grain yield, wet gluten content, sedimentation value, and protein content. The study concludes that the two investigated populations displayed a similar yield potential and baking quality parameters compared to the average of organic inbred varietes, being all allocated to quality class “E”, the highest wheat quality class in Germany. In general, the OHM wheat populations showed a higher stability for several baking quality parameters under the diverse environments and populations tend to have a higher yield stability compared to inbred varieties. Weedon and Finckh (2019) compared composite cross populations (CCPs) of wheat from three different genetic backgrounds with organic inbred varieties for eight to ten years concerning yield performance and stability under organic and conventional conditions. Under organic conditions, no significant differences between the heterogeneous CCPs and the homogenous inbred varieties could be found for yield, whereas under conventional conditions the inbred varieties yielded significantly higher than the populations (Weedon & Finckh, 2019). The included CCPs were developed for high yield, i.e., the parental lines to conduct the crosses were chosen based on their high yield performance which is generally related to lower baking quality. Another study from the same authors investigated CCPs for ten years and found out that the genetic background had a significant impact on the performance of the investigated populations in the first five years, but not anymore in the last five years. The CCPs yielded comparably to investigated inbred varieties under organic conditions, but were out yielded by them under conventional conditions (Weedon & Finckh, 2021). A study by Baresel et al. (2022) supports the finding that heterogenous CCPs often perform better than commercial homogeneous inbred varieties with respect to yield and yield stability under organic conditions. Therefore, these authors concluded that the good performance of CCPs is more linked to the high genetic diversity of the populations rather than to their genetic background/makeup. However, under conventional conditions the CCPs were outyielded by the conventional inbred varieties (Baresel et al. 2022).

When looking at populations' performance, the differences between low-input and high-input systems should be taken into consideration. In a study by Siegmeier et al. (2019), the CCPs of wheat showed a stable but moderate yield without Nitrogen (N) fertilization, whereas with N fertilization, only one out of the two heterogeneous populations outyielded the respective organic inbred varieties. The study points out the often higher protein content of heterogeneous populations under organic management, which can lead to a higher market price and therefore to a higher economic efficiency of populations. The opportunity of higher price for the grain or the final product was mentioned in our evaluation workshops among the motivation for own-benefit from being part of the FURAT value chain.

The assumption that populations tend to perform better in low-input systems was also the base for a study by Hond-Vaccaro et al. (2023), which compared the performance of a CCP and an organically bred pure line in two temperate agroforestry systems. The CCP could outperform the pure line concerning yield, but the pure line performed better with respect to quality. Nevertheless, this study was only conducted in one year, meaning that the CCP was not adapted to the location at all.

Based on the yield stability and the high protein content, the authors suggest to use CCPs in case of risk aversion (Siegmeier et al., 2019). This is in line with the opinion of the interview partners and workshop participants, stating that populations can buffer the risk for farmers.

Regarding the literature data on yield and quality output and stability, it has to be mentioned that most of the published studies compare populations and varieties over a time frame of only two to four years, which is most likely not enough for a full adaptation to the specific location. However, this trait is the one from which a lot of benefits result, especially the yield stability and quality stability. Only the studies of Weedon and Finckh compared the tested CCPs over eight to ten years (Weedon & Finckh, 2019, 2021), which seem to be suitable time periods to assess the performance of populations taking into account the local adaptation. In order to assess the local adaption of CCPs, Weedon et al. (2023) compared the performance of CCPs with identical genetic background that were grown for 5 years in Germany and in Hungary, respectively, with those CCPs that were circulated between different European countries. They found that continuously applying differential selection environments increased e.g., the number of awned ears of the CCP maintained in Hungary as adaptation to drought to stripe rust, fit the overall more continental environmental conditions with colder winters and lower precipitation in Hungary. However, the overall similarity of the CCPs based on their origin and cycling history for agronomic traits indicates a high buffering potential under highly variable and stressful environmental conditions (Weedon et al. 2023). Thus, heterogeneous populations provide an interesting alternative to genetically uniform wheat varieties and contribute at the same time to the conservation of genetic resources for future use. The results of the available studies on the high buffering capacity of CCPs are in line with the experiences of the interview experts as well as the workshop participants.

**Adaptation to low-input conditions**

FURAT was also described to have a good weed competitive ability which makes it easy for farmers to do farming without any use of herbicide (in accordance with organic cultivation) and minimizing the need for mechanical weeding. This is linked to the height of plants, with taller plants usually being better able to compete with weeds, especially when growing tall in early growing stages. This is the case for all cereal plants, not only for OHM cultivars. What comes as a disadvantage with tall plants is the risk of lodging in the field. Landraces are often taller that modern varieties and more prone to lodging. FURAT has tall plants compared to modern varieties, but differents layers of heights due to the great diversity within the cultivar. What was described for wheat mixtures by Lazzaro et al. (2018) can as well be applied for OHM cultivars: the diversity within the plant and within their heights increases the weed competitive ability and prevents the cultivar from lodging as the smaller plants support the taller ones. This can have a substancial influence on the cultivars performance in the field (Lazzaro et al., 2018). Therefore, FURAT and OHM with similar makeup in terms of plant height tends to be more vulnerable to lodging than modern varieties, as mentioned by some experts, but less vulnerable to lodging than landraces (Bosi et al., 2023).

### Local adaptation

A recent study that compared several old varieties and two heterogeneous populations in two marginal locations in Italy came to the conclusion that the investigated populations performed well, however, one population showed a better yield stability than the other. This is probably due to the genetic background. According to the authors of this study, farmers were particularly interested in populations for their local adaptation. In marginal areas, this could be an essential advantage to reach good and stable performance (Bosi et al., 2023). This is in line with the results of our stakeholder evaluation study, where farmers also ranked the local adaptation to be one of the most promising arguments for the use of OHM cultivars. However, Knapp et al. (2020) couldn't find significant differences when assessing the genes of 10 generations in 4 locations. The locations differened in management practices (organic and conventional). The authors state different possible reasons for these results: it could be that more generations would be needed to find singinficant adaptation. Another point discussed by the authors is the suitability of the chosen genetic markers, assuming that they might not have been suitable to assess a measurable effect on the genetic composition of the populations. Furthermore, it may be that the environmental conditions of the study locations were similar, resulting in all popuhlations adapting to the same conditions, or that the weather fluctuations overlayed the environmental conditions at the locations.

### Buffering capacity

Interestingly, Weedon et al. (2023) came to the conclusion that no matter if populations are adapted to a location or not, they are able to buffer external stress, for instance drought stress, as it happened during their experimental phase with a CCP originating from the UK. They see a great potential in well planned OHM cultivars to perform stably under stressful conditions (Weedon et al., 2023). This backs up the experience of FURAT value chain stakeholders in our study that stated that the buffering effect is much higher for OHM than for uniform lines.

### Baking quality

While genetic heterogeneity may be an advantage with respect to stress tolerance and yield stability, Heiden et al. (2023) wanted to study the performance of CCPs with respect to baking quality. They tested three CCPs of different genetic background, one developed in Hungary, one in Germany and the population of this case study, *FURAT Floriddia* (referred to *Solibam Floriddia)* in Germany and Switzerland in comparison to inbred varieties. They assessed ash content, Zeleny sedimentation volume, Hagberg falling number, wet gluten content, gluten index, dough rheological properties (by farinograph and extensograph), baking test (Austrian "Kaisersemmel"), as well as volume measurements. Although the three CCPs delivered low dough parameters, the baking test of the German and Hungarian CCPs was satisfying, while *Solibam Floriddia* was disclassified despite its high protein content. Heiden et al. (2023) pointed out that on one side the CCPs were not adapted to the test locations and the parental material might not been specifically selected for baking quality, which is certainly true for *FURAT Floriddia* which aimed for maximum genetic diversity. The importance of the genetic background for achieving high quality in differing environments was also stressed by Baresel et al. (2022). The finding of a poor gluten quality of *Solibam Floriddia,* however, contradicts with the statements of the interview and workshop participants that work with FURAT, who reported a good gluten quality. This could be due to the difference in processing the raw material. The participants of the interviews and workshop in this study are processing the raw material in an artisanal way, and explained their own aspiration to adapt their work to the raw material. Certainly, this is a different approach than in the industry, where the material is supposed to adapt to the need of the processor. This is in line with the experience by Vindras-Fouillet et al. (2021) that mention that an adapted bread-making process is needed to enhance the qualities of population varieties in the conclusion of their study on the sensory and nutritional quality of nine population varieties resulting from a ten-year participatory plant-breeding process in France compared to two commercial pure-line varieties.

**Nutrition and health traits**

Unfortunately, there is a lack of studies investigating if products from populations are healthier for consumers than products from pure lines, as stated by many interview participants working with FURAT. Spaggiari et al. (2022) assessed the nutritional, chemical and sensory qualities of bread from OHM cultivars compared to conventional wheat varieties. The results show that the chemical and nutritional values don't differ, while the sensory qualities are assessed to be very good for the products from heterogeneous population wheat. Vindras-Fouillet et al. (2021) also report that differences in gluten tenacity impacted the Maillard reaction, the origin of the bread's aroma in their sensory evaluation of bread from wheat populations vs pure lines in France.

### 3.2.7 Case study summary

This case study aimed to investigate the benefits and costs of using the wheat population FURAT for organic wheat cultivation. Where possible, the use of FURAT as example of possible OHM was compared to the use of uniform lines under the same conditions. However, the comparison with a single specific type of uniform cultivar (conventional pure line, organically bred pure line, old variety, landrace) was not possible because of the diversified experiences and baseline for comparisons by experts and farmers according to the topic/indicator. Expert interviews and a stakeholder workshop were conducted for the investigation. The following benefits and costs were found during expert interviews and validated in a workshop:

**Table 7: List of benefits of using OHM perceived by the stakeholders.**

| Type | Stakeholder | Potential benefits of OHM cultivars as of expert interviews |
|---|---|---|

| | | |
|---|---|---|
| Social/ well-being | Breeders | Breeding activities strongly embeded in the value chain |
| | Farmers | Seed sovereignty (possibility to produce own seed), farmers are owners of seed |
| | | Independency from the global seed and wheat market |
| | | Suitable approach for farmer and community involvement in development and mainataince of the cultivar (Participatory Plant Breeding) |
| | | Community building, connecting, stronger collaboration along the value chain |
| | | Unique seed and possibility to create a "farm cultivar" |
| | | Collaborative innovation (including social innovation, beyond simple technical innovation) |
| | Processors/ consumers | Very good taste |
| | | Good nutritional value |
| | | Digestibility of products (bread) |
| | Society | Diversity of diets and taste |
| | | Seed as common good, no patents, no IPR |
| Economic | Breeders | Lower breeding costs |
| | | Quick improvement through adaptation |
| | Farmers | Yield stability |
| | | Quality stability |
| | | Good disease resistance |
| | | Adaptation to the growing location over the years |
| | | Comparable weed competitive ability |
| | | Higher nutrient use efficiency and water use efficiency |
| | | Baking quality for artisanal baking |
| | | Gluten quality for artisanal baking |
| | | Long shelf life of products (bread) |
| Ecological | Farmers | Genetic diversity within the cultivar |
| | | Buffer effect against external stress, e.g. extreme climatic situations |
| | | Facilitate organic cereal cultivation without the use of syntetic fertilisers and pesticides |
| | | Positive influence on soil health |

| | | |
|---|---|---|
| | Society | Dynamic management of genetic diversity thorugh cultivation and use |
| | | A support to adaptation of agriculture to climate change (Higher genetic diversity and therefore better adaptability) |
| | | No GMO and NGTs |
| | | Seeds as common good |
| | | Cultivar is bred in the same region, where it is cultivated |

**Table 8: List of costs of using OHM perceived by the stakeholders.**

| Type | Stakeholder | Potential costs of OHM cultivars as of expert interviews |
|---|---|---|
| Social/ well-being | Breeders | Traceability management |
| | Farmers | High responsibility |
| | | Requires high effort from stakeholders |
| | | Very knowledge intensive for stakeholders |
| Economic | Farmers | Specific value chain is needed |
| | | Risk of losing the adapted seed ( if there is no back up storage) |
| | | Populations are usually not made for maximized performance (concerning yield and quality) |
| | | Seedborne disease management |
| | | Seed conservation and maintenance |
| | | Seed supply and limited choice of populations on the market |
| Ecological | Farmers | Risk of losing genetic diversity within the population because of strong adaptation to single location |

These are the benefits and costs perceived by stakeholders being part of the value chain of one specific OHM wheat cultivar. Some of the perceived benefits and costs are in line with current literature, including the stability of yield and quality, the genetic diversity, the local adaptation and the indenependance from global seed comapanies. Other perceived factors are contradicting with other scientific results, like the gluten quality. Some factors can be considered as challenges when comparing to the conventional breeding system and require a change of perspective. The absence of IPRs and royalties is was feared by some breeders, but mentioned as a positive point by many more, provided that the breeding work is embeded in the value chain. The same applies for the fact that farmers are perceived to have a higher responsibility, which can be challenging but also empowering. Building up a functioning small value chain might require some effort by all stakeholders, but comes with advantages like sharing the responsibility and the knowledge which is needed to successfully grow populations.

We tried to quantify the benefits and costs through developing indicators that were validaded in a stakeholder workshop. For some indicators the quantitative validation through the stakeholders worked well, wheras for others, the stakeholders had difficulties. Most experts interviewed and stakeholders in the workshop agreed that OHM cultivars have advantages, that cannot be quantified (yet). Nevertheless, more literature is required to further investigate the advantages and disadvantages of populations and to back up the results of our study. In total, the stakeholders working with OHM are very convinced and engaged to find new ways to work with populations and spread the knowledge about them.

## 3.3 Case study 2: Open pollinated beetroot cultivar in Germany, potential Organic Variety (OV)

### 3.3.1 Case study Description

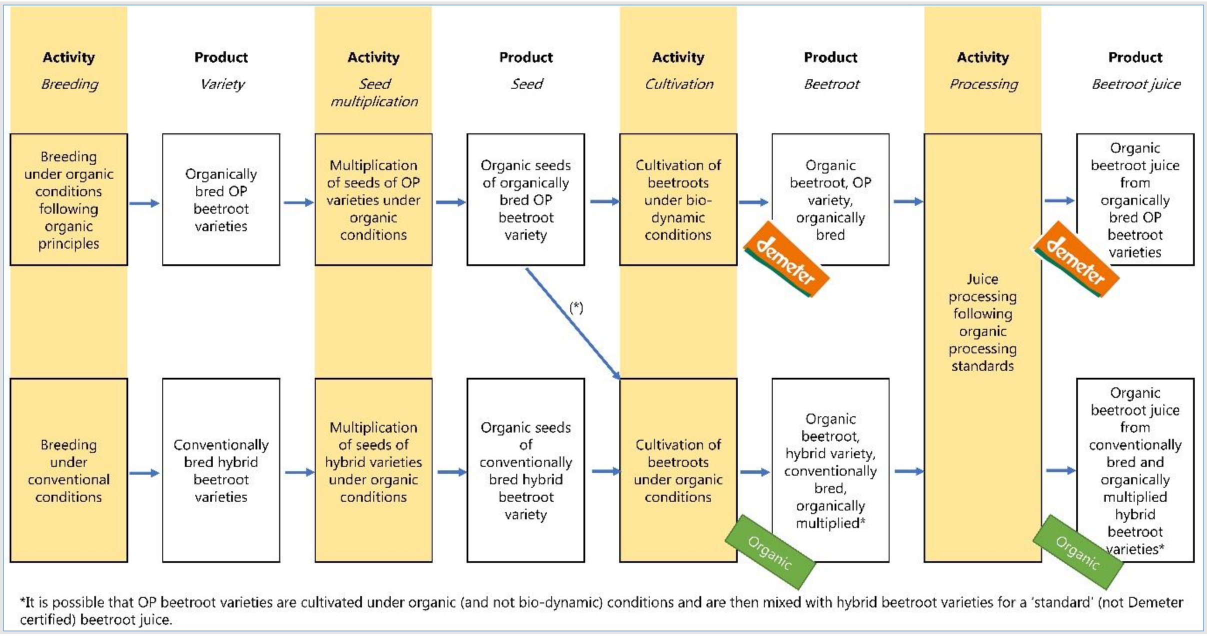
In Europe, open pollinated (OP) varieties have been largely replaced by homogeneous F1-hybrids which are dominating the market for many crop species – also the organic market. This is especially true for maize and many vegetable crops (Stadtlander, 2005). As a F1-hybrid cannot be regrown without loss of performance, many organic breeding initiatives like Kultursaat e.V. and Saat:gut e.V. focus on breeding new OP varieties to safeguard farmers' privilige for farm-saved seed. The private label organisation bioverita for organically bred cultivars, certifies only organically bred non-hybrid cultivars (https://bioverita.ch/en/825-2/organic-vegetable-breeding/). In addition, there is a discussion about the complience of different breeding techniques to the principles of organic agricultue (IFOAM, 2017; Nuijten et al., 2016). An example is cell fusion, which is not applied by organic plant breeders, but used widely to obtain male sterile plant for hybrid seed production in brassica vegetables. Some private labels in Germany have already banned cultivars based on cell fusion for organic production, due to the fact that the integrity of life and more specifically the genotypic integrity is violated and species specific crossing borders are overcome (Nuijten et al., 2016). Moreover, cross-pollinating OP varieties contain more genetic variability, compared to hybrids, allowing for on-going adaptations in response to environmental and human selection.

To evaluate the benefits and costs of organically bred open pollinated (OP) varieties at different levels of the value chain we chose organic beetroot for juice production in Germany as focus case. Benefits and costs were evaluated in relation to conventionally bred and organically multiplied F1-hybrid varieties (= baseline) in the context of organic farming.

If we speak of OP beetroot varieties in this report, we always mean organically bred and organically multiplied (= multiplied under organic conditions), open pollinated beetroot varieties. In the case of F1-hybrids, we always mean conventionally bred, organically multiplied F1-hybrid beetroot varieties. Red beet is an outcrossing species and F1-hybrids are dominating the market (also in organic). OP varieties allow farmers to multiply their own seed, while for F1-hybrids seed needs to be purchased each year.

Figure 5 shows the value chain of organically bred OP beetroot varieties grown for juice making (upper value chain) and the value chain of conventionally bred and organically multiplied hybrid beetroot varieties for juice making (lower value chain) in a simplified fashion.

Figure 5: Value chain of organic beetroot for juice (own illustration).




Both value chains consist of four levels: breeding, seed multiplication, cultivation, and processing. Except for the levels of cultivation and processing, value chain actors are different for the two value chains. That is, a farm can both grow OP and F1-hybrid beetroot varieties, have multiple certifications, and act in both value chains at the same time. Also, a juice processor can process both OP and F1-hybrid beetroot varieties and either mix them or sell them as two separate products with different labels. In contrast, there is no actor who does both, organic and conventional breeding and there is no actor who multiplies both organically bred OP varieties and conventionally bred lines to produce F1-hybrid seed under organic conditions.

In beetroot juice making with organically bred OP varieties, Robuschka and Gesche are most prominent, particularly Robuschka. Both, Robuschka and Gesche have been developed in Germany by Kultursaat e.V. and Saat:gut e.V., respectively. Their seeds are multiplied and sold by Bingenheimer Saatgut AG. Both cultivars are certified as organically bred varieties by the private standard of the association Bioverita (www.bioverita.ch). However, both varieties have been released before the temporary derogation for the official registration of OV was available. This is only possible since July 2023 and until now only for carrots, kohlrabi, wheat, barley, rye and maize.

Figure 6: Varieties Robuschka (Kultursaat e.V.) and Gesche (Saat:gut e.V). Pictures are taken from the Bioverita website (https://bioverita.ch/en/varieties/vegetable-varieties/ )

In the current study we focused on actors that form part of the upper value chain. Hence, an 'experience-based' comparison between OP and F1-hybrid varieties was – strictly speaking – only possible for the actors at farm and processing level.

### 3.3.2 Case study specific methodology for the selection and evaluation of indicators

For the case study on the benefits of open pollinated (OP) beetroot varieties, indicators were selected based on relevant literature and complemented and validated through three explorative interviews with experts with expertise in the area of organic breeding and beetroot cultivation:

**Table 9: Experts (indicated as "E") interviewed for beetroot case**

| ID | Function | Field |
|---|---|---|
| E1 | Researcher (Dr. sc. agr.) | Agricultural Sciences |
| E2 | Researcher M.Sc. | Horticultural sciences |
| E3 | Researcher | Bio-dynamic Agriculture |

Relevant literature included a number of reports on experiments with OP and F1-hybrid beetroot varieties in different experimental stations in Germany published on Hortigate, a horticulture information network (https://www.hortigate.de/). Another two important sources of information were the doctoral thesis by Yasaminshirazi et al. (2020) and the doctoral thesis of Ficiciyan (2020). The former resulted from the project Beta-Divers, funded by the Federal Ministry of Food and Agriculture of Germany (BMEL) and includes a paper on the "Agronomic Performance of Different Open-Pollinated Beetroot

Genotypes Grown Under Organic Farming Conditions". The latter resulted from the project RightSeeds, funded by the Federal Ministry of Education and Research and investigates the "Performance of organic and conventional crop varieties and species mixtures under stress" (no focus on beetroot specifically). Another important source of information, although there was no specific focus on beetroot, is a study by the Louis Bolk Institute on the quality and performance of OP varieties (Nuijten, 2020).

The goal of the expert interviews was to get a list of potential benefits of organically bred OP beetroot varieties and validate indicators identified relevant from the literature. For the interviews the following interview guideline was used (Table 10):

**Table 10: Interview guideline for beetroot case**

| **Interview section** | | **Content** |
|---|---|---|
| 1 | **Introduction** | Goal of Liveseeding.<br>Fundamental research question of the current study: What are the benefits of organically bred open pollinated (OP) varieties compared to conventionally bred F1-hybrids?<br>System boundary: Value chain for organic beetroot juice in Germany.<br>Method: Multicriteria analysis (MCA) with value chain actors.<br>Output: Communication narratives. |
| 2 | **Motivation** (Question 1) | What is the motivation of organic farmers to grow organically bred OP varieties instead of F1-hybrids? |
| 3 | **Shared values** (Question 2) | Which values do the actors of the value chain for organic beetroot juice from OP varieties share? |
| 4 | **Video on the benefits of organic breeding** | Film on organic breeding of OP varieties, which the regional organic wholesaler Grell Naturkost published together with Bioverita, Bingenheimer Saatgut and Bodan Naturkost, entitled 'Where does organic start for you?' (https://www.youtube.com/watch?v=et3XeyW4NSo). |
| 5 | **Discussion** of the video | Do you agree with the benefits mentioned?<br>How important is each benefit to you?<br>Can you think of other important benefits? |
| 6 | **Farmers expectations** (Question 3) | What needs/ expectations do organic farmers have regarding beetroot varieties when they grow them for juice producers? |
| 7 | **Meet the needs** (Question 4) | To what extent do organically bred OP beetroot varieties fulfill these needs? Use indicators to evaluate. |

| 8 | **Closure** | Further steps |
|---|---|---|

The results of the three interviews and the full list of validated indicators is presented in chapters 3.3.3 and 3.3.4.

Indicators were planned to be evaluated using a multi-actor workshop to stimulate discussions among value chain actors. Due to the length of the value chain, however, it was not possible to bring all actors at one table. Indicators were therefore evaluated using individual online interviews with a duration of 1.5 hours. Only the interview with Gesa and Beutelsbacher involved four people, two representing Gesa and two representing Beutelsbacher. All interviews were conducted in April and May 2024.

Table 11 shows the ten value chain actors who participated in the evaluation of indicators:

**Table 11: Study participants beetroot case (B = breeder, S = seed producer, F = farmer, P = processor)**

| ID | Value chain level | Function | Organisation | Country | Certification |
|---|---|---|---|---|---|
| B1 | Breeding | Breeder (variety: Gesche) | Saat:gut e.V. | Germany | Bioland, Bioverita |
| B2 | Breeding | Breeder (variety: Robuschka) | Kultursaat e.V. | Germany | Demeter |
| S1 | Seed multiplication | Advisor | Bingenheimer Saatgut AG | Germany | Demeter, Bioland, Naturland, EU Bio |
| F1 | Cultivation | Farmer and advisor | NA | Germany | Naturland |
| F2 | Cultivation | Farmer | NA | Netherlands | Demeter, Naturland |
| F3 | Cultivation | Farmer | NA | Germany | Demeter, Bioland |
| F4 | Cultivation | Farmer | NA | Netherlands | Demeter |
| P1 | Processing | Processor | Voelkel | Germany | Demeter |
| P2 | Processing | Processor | Gesa & Beutelsbacher | Germany | Demeter |

We selected two organic breeders, one representative of a multiplier of organically bred OP varieties (Bingenheimer), four farmers, and two organic processors. One of the two organic processors 'consists' of two separate organisations (Gesa and Beutelsbacher), one of which sources and processes the juice (Gesa) and one that bottles and sells the juice (Beutelsbacher). As they together represent the 'processing activity' in the value chain, the two organisations are treated as one actor in this study.

In beetroot juice making with organically bred OP varieties, Robuschka and Gesche are most prominent. Therefore, the breeders of these two varieties were selected for the study. Both, Robuschka and Gesche are multiplied and sold by Bingenheimer Saatgut AG, which is why a representative from Bingenheimer was selected. When it comes to Demeter certified vegetable juice making from organically bred OP varieties in Germany, the most important actors are Gesa, Beutelsbacher, and Voelkel. All three organisations could be recruited to participate in the study. It was a challenging task to recruit farmers. Therefore, three of the four farmers interviewed were recruited with the help of Voelkel and are therefore farms who supply Voelkel with OP beetroot varieties. This is important to keep in mind for the interpretation of results.

### 3.3.3 Results of the explorative expert interviews

Through the interviews with experts, the following potential benefits (Table 12) and costs (Table 13) of organically bred, open pollinated (OP) beetroot varieties were identified.

**Table 12: Potential benefits of organically bred OP cultivars as of expert interviews**

| Type | Stakeholder | Potential benefits of organically bred OP cultivars as of expert interviews |
|---|---|---|
| Social/ well-being | Farmers | Improved seed sovereignty (possibility to produce own seed, no dependence on large seed companies) |
| | | Higher autonomy and higher self-sufficiency |
| | | Not support conventional sector/ full independence from conventional sector (integrity, authenticity, organic from the start) |
| | | Community building, connecting, stronger collaboration along the value chain |
| | | Knowledge sharing |
| | | Sense of purpose/ meaning |
| | Society | Increased awareness of importance of seed |
| | | Larger choice and diversity in form, colour, taste, bioactive compounds |

| | | |
|---|---|---|
| | | Improving culinary culture of people |
| | | Varieties are considered as common good and embedded in regional culture |
| Economic | Breeders | Lower breeding costs |
| | | OP varieties are part of the breeding gene pool for further improvements |
| | Farmers | Reduction of input costs (OP variety seeds are cheaper) |
| | | Similar yield of OP varieties compared for F1 hybrids for several crops, including beetroot |
| | | Comparable disease resistance |
| | | Comparable drought tolerance |
| | | Comparable weed competitive strength (if comparable seed quality) |
| | | (Higher?) nutrient use efficiency |
| | Processors/ consumers | Adjustment for various processing and uses (juice vs. fresh consumption), greater output per raw material (higher dry matter content) |
| | | Good taste (higher Brix content for beetroot) |
| | | Diversity of food in colours and taste – possibility to respond to diversity in consumer preferences and for new products and the potential to obtain premium price (diversification potential) |
| | Society | Independence of the organic sector (from the conventional sector) |
| | | No patents, no plant variety protection (OP varieties = common good[6]) |
| | | Good nutritional value with health benefit (antioxidative potential of phenols in beetroot) |
| Ecological | Farmers | Potential of local adaptation (possibility to produce own, more locally adapted farm variety suitable for organic production) |
| | | Less external input needed, less contamination |
| | | Short local value chains less greenhouse gas emissions |

[6] „F1 hybrids are not stored as a genetic resource in the gene bank, as only the parent lines can be multiplied and preserved. The parent lines are the private property of the breeders." (Expert)

| | | |
|---|---|---|
| | Society | Higher genetic diversity and therefore better adaptability to different climatic conditions |
| | | Adaptation to climate change (Organic breeding mainly takes place in the field, i.e. under the given conditions and not in the laboratory. In this way, the current climatic conditions are integrated |
| | | No genetic manipulation (- the plant's natural ability to reproduce is respected and with that natural crossing barriers) |
| | | Higher agrobiodiversity and conservation of genetic diversity |
| | | Variety is bred where it is cultivated (i.e. at least in the same country or on the same region) |

**Table 13: Potential costs of organically bred OP cultivars as of expert interviews**

| Type | Stakeholder | Potential costs of organically bred OP cultivars as of expert interviews |
|---|---|---|
| Social | Society | Lower yield can result in higher food prices. |
| | | Financing of organic breeding is not secured in the long term, depends a lot on volunteer work, foundation, consumer or tax payer support, thus competing with other social activities |
| Economic | Farmers | Limited seed availability. |
| | | Lower seed quality (less homogeneous and slower field emergence/ juvenile development, therefore slightly lower weed competitive strength at the beginning – but overall cultivation effort not affected). |
| | | Produce is more heterogeneous in terms of size and shape (but no issue for juice making – marketable yield to juice makers very high). |
| | | Lower yield (yield gap very much dependant on plant species/ cultivar). |

| | | |
|---|---|---|
| | | Lower storability (negative correlation between storability and product quality). |
| | Processors | Higher total dry matter content (TDMC). |

Yield was included both as a benefit as well as a cost. Depending on the cultivar, the yield of OP varieties can be almost comparable with F1-hybrids, which can be considered a benefit, or much lower, which is a cost.

Regarding disease resistance, drought tolerance, and weed competitive strength, the performance of OP organic varieties was perceived at least comparable to F1-hybrids, which is interpreted as a benefit. Regarding drought tolerance two experts agreed that "a plant species cannot jump out of its role. Some plant species are better adapted to drought than others". Regarding weed competitive strength it was mentioned that a slightly slower and less homogeneous field emergence and juvenile development may increase weeding in the early phase of plant growth, but without significantly affecting the overall cultivation effort. In addition, as experts specified, the less homogeneous and slow field emergence and juvenile development is not related to the variety but to seed processing, i.e. seed quality.

Nutrient use efficiency was mentioned as a breeding target of organic breeding and was therefore included as a potential benefit. The same holds for good taste and good nutritional value.

Storability can differ between organically and conventionally bred varieties and was mentioned as a potential cost of organically bred varieties (which are bred for high quality and good taste) based on a study by the Louis Bolk Institute on carrots and pumpkin which suggests that storability and quality (including taste) are negatively related: "There can be a negative relation between storability on the one hand and taste and quality on the other hand. It implies that varieties with good taste and quality are more difficult to store than the commonly used varieties by farmers" (Nuijten, 2020, p. 5). Generally, it has to be noted, however, that it is complicated to attribute storability, taste, and quality to a variety as all of these aspects (also) depend on soil quality (clayey vs sandy soil), weather conditions, crop management and time of harvest.

Based on the same study by Nuijten (2020), a higher total dry matter content (TDMC) was mentioned as a potential cost of OP beetroot varieties. The study suggests a negative relationship between fresh matter yield (lower for OP beetroot varieties) and total dry matter content (higher for OP beetroot varieties). Depending on the end product, this can be an advantage or disadvantage. In the case of juice, it is a disadvantage, as it implies a lower juice yield.

A reduction or increase in inputs (e.g. quantity of fertilizer used) was not mentioned as a potential benefit or cost.

### 3.3.4 List of indicators and statements

The list of indicators and statements which was developed combining the findings from the expert interviews with the insights from literature and assessed with value chain actors can be found in Annex 2.

For the assessment of indicators, we either used a specific parameter – if available and feasible for participants to assess – or a 9-point-Likert scale. If it was considered feasible for participants to assess OP beetroot varieties relative to F1-hybrids, a relative scale was used, if not, an absolute scale was used:

**Example for a relative scale to compare OP variety to F1-hybrid:**

1 = significantly lower; 3 = lower; 5 = comparable; 7 = higher; 9 = significantly higher

**Example for an absolute scale to rate OP variety:**

1 = very bad, 3 = bad, 5 = average, 7 = good, 9 = very good

For the assessment of statements, the following 9-point-Likert scale was used:

**Scale of agreement to a specific statement:**

1 = do not agree at all, 3 = do not agree, 5 = average, 7 = agree, 9 = fully agree, 88 = it depends, 99 = don't know

### 3.3.5 Evaluation of indicators and statements

As one breeder pointed out, the costs and benefits of open pollinated organic varieties compared to F1-hybrids depend heavily on the plant species or crop:

"I am of the opinion anyway that the use of hybrid varieties offers advantages or disadvantages that are very plant-species-specific. Beetroot is certainly a crop where you could actually do completely without hybrid breeding. But there are other crops where the situation is perhaps somewhat different. So, it is quite good to convey a differentiated picture [a crop-specific picture]." (Breeder)

In what follows, we first present the financial benefits and costs that arise in the value chain for organically bred OP beetroot varieties and then list the advantages and disadvantages of organically bred OP beetroot varieties as compared to conventionally bred F1-hybrid beetroot varieties in the context of organic farming which were identified in the interviews with experts and value chain actors.

#### 3.3.5.1 Financial benefits and costs in the value chain for organically bred OP beetroot varieties

The financial benefits and costs presented here, apply for the following scenario: A bio-dynamic farm (Demeter certified) that grows the organically bred, open pollinated (OP) beetroot variety for a juice processor. The time span is of one year.

**Table 14: Financial benefits and costs in the value chain for organically bred OP beetroot varieties**

| | | OP | | Hybrid | | Diff |
|---|---|---|---|---|---|---|
| **Indicator** | **Parameter** | **Min** | **Max** | **Min** | **Max** | |
| Breeding | | | | | | |
| Breeding duration | years | 16.0 | 16.0 | NA | NA | NA |
| Breeding costs | EUR/ year | 5'000.0 | 5'000.0 | NA | NA | lower |
| Breeding costs | EUR/ variety | 80'000.0 | 80'000.0 | NA | NA | lower |
| Costs for maintenance breeding | EUR/ year | 3'000.0 | 5'000.0 | NA | NA | NA |
| Seed production | | | | | | |
| Quantity of seed of OP beetroot varieties sold | kg/year | 1'900.0 | 2'240.0 | NA | NA | NA |
| Number of hectars cultivated with Robuschka if stocking density 20 plants/m2 (assuming 51.4 plants/gram of seeds) | ha | 488.6 | 576.0 | NA | NA | NA |
| Number of hectars cultivated with Robuschka if stocking density 40 plants/m2 | ha | 244.3 | 288.0 | NA | NA | NA |

| | | | | | | |
|---|---|---|---|---|---|---|
| (assuming 51.4 plants/gram of seeds) | | | | | | |
| Cultivation | | | | | | |
| Planned plant/ stocking density | plants/m2 | 20.0 | 40.0 | 20.0 | 40.0 | equal |
| Quantity of seeds for planned plant/ stocking density | units/ha (1 unit = 100'000 seeds) | 2.5 | 3.5 | 2.5 | 3.5 | equal |
| Germination capacity | % | 85% | 95% | 85% | 95% | equal |
| Seed price | EUR/unit (1 unit = 100'000 seeds) | 160.0 | 170.0 | 200 | 240 | lower |
| Seed cost (20 plants/ m2) | EUR/ha | 400 | 425 | 500 | 600 | lower |
| Seed cost (40 plants/ m2 | EUR/ha | 560 | 595 | 700 | 840 | lower |
| Cultivation effort | NA | NA | NA | NA | NA | equal |
| Storability | months | 9 | 9 | 9 | 9 | ?[7] |
| Yield | tons/ha | 40 | 60 | 50 | 70 | lower |
| Marketable yield share | % | 85% | 90% | 90% | 95% | lower |
| Price paid by the juice processor for marketable yield | EUR/ton | 180 | 180 | 150 | 150 | higher |
| Total income | EUR/year | 6'120.0 | 9'720.0 | 6'750.0 | 9'975.0 | lower |

[7] The experience oft he value chain actors interviewed does not allow to make a judgement here.

| Processing | | | | | | |
|---|---|---|---|---|---|---|
| Number of farms and other entities (producer association, traders) from which beetroot is sourced | Number | 20.0 | 20.0 | 100.0 | 100.0 | lower |
| Quantity processed | tons/year | 6'000.0 | 6'000.0 | 12'000.0 | 12'000.0 | lower |
| Processing effort | NA | NA | NA | NA | NA | equal |
| Brix content | % | 12% | 14% | 10% | 12% | higher |

Assuming a breeding duration of 16 years, the costs for the organic breeding of Robuschka (including the breeding of the umbrella variety Rote Kugel 2) amount to 80’000 EUR. One of the breeders judged this to be about 10 times lower than the conventional breeding costs for a hybrid.

Based on 1’900 to 2’240 kg of Robuschka seeds sold per year by Bingenheimer Saatgut and a stocking density of 20 or 40 plants per square meter, the number of hectars cultivated with Robuschka amount to 490 to 580 hectars (for the lower stocking density) or 240 to 290 hectars (for the higher stocking density).

With a stocking density of 20 plants per square meter, the seed cost for Robuschka amounts to 400 to 425 EUR/ha. For hybrid varieties we estimate a seed cost of 500 to 600 EUR/ha. With a plant stocking density of 40 plants per square meter, the seed cost for Robuschka amounts to 560 to 595 EUR/ha and that for hybrids to 700 to 840 EUR/ha.

Based on a farm gate price of 180 EUR/ton for Robuschka, a farmers income ranges from 6’120 (minimum marketable yield) to 9’720 EUR/year (maximum marketable yield). For a hybrid variety with a farm gate price of 150 EUR/ton, the income ranges from 6’750 (minimum marketable yield) to 9’975 EUR/year (maximum marketable yield).

Both cultivation and processing effort and related costs were stated not to differ between OP and F1-hybrids and were therefore not further explored.

Based on the evaluation of the two processors interviewed, they source Robuschka from about 20 farms and hybrid beetroot varieties from about 100 farms. The quantity of beetroots processed was indicated to amount to 6’000 tons/year for Robuschka and 12’000 tons/year for hybrid beetroot varieties. As the number of farms from which

Robuschka is sourced is about one fifth, the quantity of Robuschka processed is probably lower, though, or the quantity of hybrids processed higher.

**How do Demeter certified farmers and juice processors who produce Demeter certified vegetable juice collaborate?**

Processors: There are three important actors who produce Demeter-certified vegetable juice on the German market: Voelkel, Beutelsbacher, and Gesa. Voelkel sources the vegetables, processes them to juice and sells the juice under the brand Voelkel. Beutelsbacher has the beetroots sourced and processed by Gesa and then bottles it and sells it under the brand Beutelsbacher.

Number of producers: According to one of the two processors, the number of producers of Demeter certified, OP beetroot varieties has been stable, which reflects the suitability of OP beetroot varieties for cultivation and further processing to juice. One processor sources the OP beetroot varieties from about 4 farms, and the other processor from about 14 farms and two traders. Beetroots are either sourced directy from the farm or through market associations and traders.

Cultivation contracts: According to one of the two processors, the cultivation contracts contain a fixed quantity which is expected to be produced and will be bought from the producer (if the quality of the produce corresponds to the product specification). If the producer agrees, the cultivation contract can also contain an optional quantity which may be produced/ bought or not.

Pricing: According to one of the two processors, prices paid depend on the season. In the main season prices are lowest. Outside the season, prices are higher. Hence, the higher the supply the lower the prices.

#### 3.3.5.2 Advantages and disadvantages of organically bred, open pollinated beetroot varieties

**Breeding level**

Advantage 1: One advantage of OP beetroot varieties identified in this study are the significantly lower **breeding costs**. One breeder estimates the costs for hybrid beetroot varieties to be ten times higher than the costs for OP beetroot varieties. According to the two breeders interviewed, the costs of breeding an OP beetroot variety amount to 3’500 and 5’000 Euros per year, respectively. Breeding the OP beetroot variety Robuschka took 16 years (including the breeding of the umbrella variety Rote Kugel 2, from which it is derived). Thus, assuming that it takes around 15 years to breed an OP beetroot variety, the total cost of breeding an OP beetroot variety amounts to 45’000 and 75’000 Euros, respectively. One breeder specified that these costs only hold if the breeding business also multiplies seeds and if it sells the beetroots that are not suitable for further breeding (those not selected). Otherwise breeding would be more costly as quite a number of plants is needed for the breeding of red beets (as they are cross-pollinators). Of course, it is also possible to cooperate with farmers to keep the breeding costs low. Once a variety is available on the market, the variety is maintained by the breeder through so-called ‘maintenance breeding’. According to the two breeders interviewed, the yearly costs to maintain an OP variety are pretty much the same as the yearly costs to breed the variety.

Advantage 2: OP varieties represent an important **genetic resource** for society but also for breeding more specifically. As stated by one of the experts:

“And then, of course, it also plays a role that open pollinated varieties are not so uniform, that they have a certain room for development, […] which I can then continue to work with as a breeder.” (Expert)

In contrast, with a F1-hybrid it is much harder to work with:

“With an F1, I'm always at the end of a production chain, so it doesn't really go any further. Of course, I can also reproduce them, but then I have the splitting and then a colourful portfolio of all kinds of things in there, where I have to start from scratch, so to speak, in order to build up a new variety, if that is possible at all. So we've already had experiences in the breeding sector where we've taken F1 varieties and thought, yes, there's everything in there that's modern now and then we split them up and then pull something out again and then you realise that, no, it took forever for some of them until you really had something useful again or nothing came out at all. So that's also interesting. That this is really the end point of a development, so to speak. And with the OP variety, a further development process is possible, so to speak. And this creates resilience.” (Expert)

### Farm level

Not an advantage, but a positive result, is the interviewed actors’ agreement to the statement: "Open pollinated beetroot varieties are **adapted to the needs of organic farmers** who grow beetroot for juice producers such as Voelkel or Gesa&Beutelsbacher." On a scale from 1 = "not agree at all" to 9 "fully agree" actors gave a value of 7 or 8. The needs of organic farmers producing beetroot for juice producers were specified to be: good yield, good seed quality and vigour (high germination capacity, fast and uniform field emergence, high share of monogerm seeds, coated seeds), good plant/ foliage health, large and heavy beetroots with a good taste and dark inner colouring, beetroots that can be harvested mechanically (leaves growth base small but not too small), beetroots with enough and long lasting foliage/ high enough leaf mass for rows to close (good ground cover), and good storability. OP beetroot varieties were stated to perform well on these criteria and sometimes even better compared to hybrids, except for seed quality, seed vigour, and yield, which were stated to be lower for OP beetroot varieties than hybrids.

Advantage 3: Even though the **yield** of OP beetroot varieties is lower than that of hybrids, the conducted interviews show that OP beetroot varieties can quite keep up with hybrid beetroot varieties, which can be considered an advantage, particularly if other crops are considered, like carrots, for which there is a significant yield difference between OP and hybrid varieties according to one processor interviewed. Whilst one breeder stated that hybrid varieties "set the bar" and OP varieties "have to come as close as possible", the other breeder stated: "I'm not at all sure whether the hybrid variety has incredible advantages [compared to OP varieties] in beetroot production. Maybe it really just needs to get out of your head that 'hybrids are always better'". Three of the four farmers interviewed stated a yield gap between hybrid and OP varieties of 8%, 15%, and 32% (one farmer has no experience with hybrids and made no statement). The advisor from Bingenheimer estimated the yield gap at 10%. Based on field experiments in Germany, the yield of OP beetroot varieties is between 10 and 20% lower. Regarding yield stability and marketable yield share, the actors interviewed evaluated both to be comparable, a little lower, or lower for OP beetroot varieties. The marketable yield share of hybrid beetroot varieties was estimated to be between 90 and 95% and the marketable yield share of OP beetroot varieties was assessed to be between 80 and 90%.

**Advantage 4:** Processors like Voelkel and Gesa&Beutelsbacher offer a **price premium** for Demeter certified, OP beetroot varieties. This should allow Demeter certified farmers to compensate for the lower yield of OP beetroot varieties. In fact, the Demeter certified farmers interviewed, assessed the economic viability of OP beetroot varieties as comparable to hybrids. Whereas Demeter certified farms profit from a price premium, other farms do not, as their OP beetroot varieties are mixed with hybrid beetroot varieties and processed to a standard (not Demeter certified) organic beetroot juice. Processors do not produce a standard (not Demeter certified) organic beetroot juice from OP beetroot varieties. One farmer stated to receive 137 and 142 EUR/ton in 2022 and 2024, respectively, for Naturland certified Robuschka – not including transport. More or less the same price (between 130 to 140 EUR/ton) was paid to another interviewed farmer for organically certified hybrid beetroots. The same farmer, who is demeter certified, stated to receive 170 EUR/ton for OP beetroot varieties (and 240 EUR/ton including transport). Two other farmers who produce demeter certified OP beetroot varieties stated to receive between 160 and 180 EUR/ton for OP beetroot varieties. One processor stated to pay an average farm gate price of around 150 EUR/ton for organic hybrid beetroots (holds for 2022 to 2024) and 170 and 180 EUR/ton for OP beetroot varieties in 2022/2023 and 2024, respectively, thus a price premium for OP varieties of 20% in 2024. The other processor stated prices including transport: 185 to 190 EUR/ton for hybrid beetroots and 200 EUR/ton for OP varieties, thus a price premium of 5 to 8%. Importantly, according to one processor, the additional work and costs incurred by the farmers are taken into account when setting the price. As additional costs vary among farmers, this also means that the purchase price for the same product can vary depending on the farm where the produce is sourced from.

It is important to point out that the price premium paid for organically bred OP varieties is cultivar specific, taking into account that the additional cultivation effort and yield gap compared to hybrids is cultivar specific. For instance, the price premium for OP carrot varieties (e.g. Rodelika) was stated to be about twice the price premium that is paid for OP beetroot varieties. It was stated that the additional cultivation effort and yield gap for OP carrot varieties like Rodelika is significant compared to hybrids. In contrast, for OP beetroot varieties the difference in cultivation effort and yield is quite low. One of the two processors specified that OP beetroot varieties are relatively high-yielding “and there are no hybrid beetroot varieties with which you would have 50% more yield” (which is probably the case for carrots).

On the economic viability of hybrids more generally one of the three interviewed experts added a critical view point:

“Breeder colleagues, who are also farmers, say that we have made no economic progress with F1 hybrids. We have no economic added value from it. We harvest more, but the more we harvest, the lower the price we are paid in the end. So it's basically a downward spiral […].” (Expert)

**Disadvantage 1:** A lower **seed quality and vigour** was stated quite a few times as a disadvantage of open pollinated beetroot varieties. Particularly, the less uniform field emergence was mentioned as a disadvantage as it results in a higher heterogeneity of beetroots. On a scale from 1 = "not uniform at all" to 9 = "very uniform", three of the four farmers rated hybrid beetroot seed between 7 and 8, and OP seed between 4 and 6. A higher share of monogerm seeds and seed coating was mentioned as a solution for a more precise seeding, a more uniform field emergence and a higher uniformity of beetroots. Whereas several actors pointed out that there is room for improvement when it comes to seed processing, a larger investment in seed processing would of course lead to an increase in seed prices. The seeds of OP beetroot varieties currently cost less than the seeds of hybrid beetroot varieties. Prices stated by farmers ranged from 200 to 240 EUR/unit (1 unit = 100'000 seeds) for organic hybrid seeds and from 103 to 174 EUR/unit for organic OP seeds. In addition, seed processing would also result in a certain amount of seed loss. As the quantity of seed produced for OP varieties is currently still at a small scale, seed processing may lead to a relatively high seed loss and consequent shortage in seed supply. Regarding seed quality one of the three experts explained:

“However, this [heterogeneity in size and shape] also depends on […] how the seed is offered and can be sown. […] For example, the seed size [the calibration window] offered by the seed suppliers plays a role. […] If the calibration window is too wide, you can't select the right sowing disc and this results in gaps in the crop when sowing. […] If I have a crop where there are no gaps and […] the carrots or beetroots are evenly spaced in the row, they don't grow so differently in size, so they grow relatively evenly. That's why seed quality is so important, to get a uniform crop, so that you don't have to sort out so many.” (Expert)

**Disadvantage 2:** It is a fact that OP beetroot varieties tend to be less **uniform in size**. All interviewed actors confirmed this. The positive side is, that for juice makers uniformity is not relevant. They accept all beetroot sizes above 4cm. A farmer stated that even beetroots of 21cm in size are still accepted. However, as stated by one farmer, a lack in uniformity can pose a problem at farm level. Less uniformity means less competitive strength against weeds in the early growing phase. Furthermore, a higher heterogeneity in size can be problematic when it comes to cutting the leaves off (juice processors only accept beetroots without leaves). If plants are not equal in hight, it is not possible to fully remove the leaves. This is a risk for the farm, as processor may not accept part of the delivered produce (as one quality requirement is full removement of leaves).

Advantage 5: In spite of a less uniform field emergence of OP beetroot varieties, three out of four farmers stated that there is no difference in **time spent on the field** during the growing period between OP varieties and hybrids. This was confirmed by the advisor from Bingenheimer. Only one farmer pointed out that there may be a little more hand weeding required in the early growing phase when the crop is a bit more unequal. Hence, overall, the cultivation effort seems to be comparable between OP beetroot varieties and hybrids, which is an advantage, particularly when comparing to other crops, like carrots, where the cultivation is more difficult in the case of OP varieties.

Regarding **storability**, neither breeders nor farmers had enough experience to make an evaluation. According to the actors, storability can be influenced by the size of the tuber and the firmness of the tuber, two characteristics which can be dependant on the variety but also on the weather conditions, growing period, soil quality, and time of harvest.

Advantage 6: A big advantage of OP varieties is their **potential to locally adapt** over time. However, as explained by the advisor from Bingenheimer, OP varieties are, per se, not more locally adapted than hybrids. OP varieties are bred at a certain location and multiplied in maybe three different locations. This does not make them more locally adapted than hybrids. Only if a farmer develops his/her own farm variety - and this is only possible with OP varieties (through on-farm selection and multiplication) - then this variety is locally adapted. One farmer stated:

"I think farmers used to do that [develop their own variety and multiply their own seed] a lot more in the past, when they really multiplied their own seeds and had varieties that were more suited to their location. But you don't have the time for that now. So, it's one thing to really make your own seeds now, but to really go through and select them and say 'Ah, this one looks particularly beautiful and I'll multiply it further', that would take even more effort. But that would of course be the wishful thinking that we could get there again. And a open pollinated variety would have the potential to be adapted to the location again." (Farmer)

The potential to locally adapt is a big advantage of OP varieties, not only for the farmer, but also for biodiversity. In the value chain analyzed in this study, farms do not develop their own farm variety. Still, local adaptation can be considered a potential or 'optional' advantage. However, as stated by one of the experts, compared to hybrids, organically bred OP varieties are 'more local'. Often times hybrids are bred and multiplied somewhere in Australia and then cultivated in Europe. The expert explained:

"[…] where we ourselves, i.e. Bingenheimer or Kultursaat breeders, have also given ourselves the limitation that we really only breed regional seeds, i.e. the breeding does not take place here somewhere on other continents, but really only where the production is." (Expert)

Advantage 7: A big advantage of open pollinated varieties is also that they produce **reproducible seeds**. In the value chain analyzed in this study, farms do not multiply their own seeds. The two breeders interviewed assessed the 'feasibility of producing good quality seed on farm' as easy. But all four farmers as well as the advisor from Bingenheimer evaluated it as hard or very hard. Hence, similarly to local adaptation, reproducibility can be considered a potential or 'optional' advantage. In fact, several farmers stated that they perceive it as an advantage to at least have the option to produce their own seed. One of the three experts stated:

“The ability to reproduce is definitely important, even if it is of course clear that most vegetable seeds are not multiplied by the producers themselves, but that they are bought anyway in the end. But by purchasing reproducible seed, there is always the possibility […] that I could just produce my own seed […], even though very few people do it.” (Expert)

According to the breeder of Robuschka, Robuschka has a high **nutrient appropriation capacity**, because it was bred on fairly light soils (sandy soils) with a medium level of fertilization. However, it is not clear how its nutrient appropriation capacity compares to hybrid beetroots. The advisor from Bingenheimer assessed OP beetroot varieties as just as suitable for cultivation on nutrient-poor soils as hybrids. Farmers interviewed stated to lack the necessary experience for an evaluation of different varieties' nutrient appropriation capacity. Hence, whether OP beetroot varieties have a comparable or higher nutrient appropriation than hybrids currently on the market would need to be further investigated.

Advantage 8: According to the breeder of Robuschka, Robuschka has a high **drought tolerance**. It was grown on light soil and also with little or no irrigation. In addition, drought tolerance was one breeding goal. Robuschka's drought tolerance was, however, not scientifically tested. Interestingly, all of the four farmers interviewed perceive Robuschka as drought tolerant. One farmer stated that Robuschka drops the leaves less quickly in drought periods than hybrid beetroots and can therefore photosynthesize for longer and continue growing. One farmer suggested that OP beetroot varieties possibly root deeper. Another farmer actually exposed Robuschka to a bit of drought stress so that it would develop good roots and observed that the plant coped well with this. On a scale from 1 = "very bad drought tolerance" to 9 = "very good drought tolerance", farmers gave hybrid beetroots a value between 6 and 7 and OP varieties a value between 7 and 8. Hence, drought tolerance could be an advantage of Robuschka compared to the hybrids grown by the farmers.

Advantage 9: The advisor from Bingenheimer shared the observation that OP beetroot varieties are less **susceptible to Cercospora leaf spots**, but stated that they are more susceptible to scab, instead – and therefore evaluated them as comparable to hybrids on average in terms of plant health. One of the farmers also shared the observation that Robuschka is less susceptible to Cercospora leaf spots and evaluated Robuschka at a value of 3 (low susceptibility to Cercospora) and Monty F1 at a value between 5 and 6 (average susceptibility to Cercospora). Another farmer, who stated not to have had any problems with Cercospora so far, generally pointed out that OP beetroot varieties are very strong plants and very well suited for organic farming and assessed their health as at least comparable to hybrids.

**Advantage 10:** Whereas hybrids are genetically uniform, OP varieties have some inherent **genetic diversity**, i.e. not every beetroot in the field is identical from a genetic point of view. This can be an advantage for a variety's resistance against diseases or tolerance to changing climatic conditions. In fact, the breeder of Robuschka pointed out that the lower susceptibility to Cercospora could be attributed to the higher genetic diversity of OP beetroot varieties.

However, there is a trade-off, at least from the point of view of the mass market: Whereas a higher genetic diversity of a variety can be an advantage for plant health, it results in a higher heterogeneity in size and shape, which is seen as a disadvantage by the market. As one expert stated:

"Organic farming, which pursues the approach of diversity, in the end meets the market, which in turn demands homogeneity. That is a discrepancy." (Expert)

**Advantage 11:** Both breeders interviewed and two farmers confirmed that OP beetroot varieties exhibit a higher **leaf mass** and linked the increased leaf mass to a high competitive strength against weeds - but not necessarily higher than the one of hybrids. Whereas one farmer observed a higher competitive strength against weeds of OP compared to hybrid beetroot varieties, three farmers evaluated the competitive strength of OP varieties comparable to hybrids. The former stated that OP beetroot varieties close the rows better and keep the leaves longer in periods of drought (which is good against late weeds).

**Advantage 12:** According to two actors and one expert interviewed, image forming methods could show that open pollinated varieties have a higher **vitality** than hybrids. According to one breeder interviewed, the higher leaf mass of OP beetroot varieties could be attributed to the higher vitality of the plants. One of the three experts interviewed formulated the difference in vigour between OP varieties and F1-hybrids as follows:

"You actually create chaos with the F1, a genetic mess. F1's are unstable, therefore you can't reproduce them. An OP variety is stable […] has developed a character." (Expert)

The breeder of Gesche described the difference in vitaly as follows:

„Boro F1 simply carries out her 'programme', Gesche reacts to the environmental conditions." (Breeder)

An vitality is not only perceived important for the plant's health, but also for human health:

"If 90% of organic vegetables are produced with F1-hybrids, then it can't be that bad. Then the varieties seem to work in organic farming. But are they really adapted from my point of view? Or does the fact that these varieties do not react to their environment and somehow 'work everywhere', because they are basically cut off from their environment show me that they are not adapted to organic farming? […] Then you can say 'yes, the F1's are not adapted [to organic farming], but they fulfil the needs of the market and the [consequent] needs of the producer for more mass or a certain uniformity." (Expert)

Advantage 13: Most actors agreed that organically bred, open pollinated varieties strengthen farms' **independence**. One of the breeders considered the statement too general and suggested that farms are 'just' more independent from large seed companies. Two farmers disagreed with the statement as they are still in a contract and still buy the seeds.

Advantage 14: One breeder and one farmer stated to have a higher **sense of responsibility** when growing open pollinated varieties:

"It has become so fashionable to always say 'the customer decides', but the question is also what the customer should know. If I'm an expert in something, then I also have a responsibility to make decisions that will enable agriculture and organic farming to still work in 5 or 10 years' time. And if we don't develop organic breeding, we're pretty much running into a dead end" (Breeder).

"The thought to have something in my own hands and in my own responsibility and to be able to create my own product that is adapted to my location, gives me a nice feeling. Responsibility is then with me and not with the breeder or seed producer for example" (Farmer).

Advantage 15: One farmer stated to feel more **secure** and more able to act against climate change with OP varieties:

"We can respond better to changes in the environment with 'reproducible' seeds due to higher genetic variability [idea of 'reproducible seeds as an insurance for the future generation']. OP varieties and organic breeding put us on a more solid ground [more security]."(Farmer).

Advantage 16: One farmer stated to have more **negotiation power** when producing demeter certified OP varieties:

"In the value chain with hybrids, the processing industry has a lot of negotiation power. They can keep prices very low. There is always a big discussion about the price. This makes work less nice. In the value chain with OP varieties, the negotiation power of the industry is less. The communication with the industry is nicer. They seem to have more respect for the farmer. They seem to be more honest, respectful, and flexible" (Farmer).

Advantage 17: One farmer perceives his/her work as more **meaningful** and **satisfactory** with OP varieties:

"The use of OP varieties is meaningful and leads to greater satisfaction. The thought that I could grow the seeds myself feels good."

Advantage 18: One farmer feels more **connected** when growing OP varieties, as he/she not only gets negative but also positive feedback from processors:

"Getting positive feedback makes me feel more connected."

Along these lines, all actors agreed that OP varieties strengthen the cooperation among actors in the value chain.

### Processing level

**Advantage 19:** According to the two juice processors interviewed, the processing of OP beetroot varieties does not require additional **processing effort or equipment** compared to the processing of hybrid varieties. This can be considered an advantage, as in the case of carrots, OP varieties do increase the processing effort, as pointed out by one processor.

**Advantage 20:** Both breeders interviewed stated that **taste** was an important breeding goal. The interviewed advisor and three out of the four farmers stated to expect a higher **Brix value** for OP than hybrids of 1 to 2%. One farmer stated that the cultivation of OP beetroot varieties reduce the risk of not reaching the quality requirement of the processor of around 10% Brix. The farmer stated: "…Brix content is […] an issue […]. If you are in a location or have a year where you don't manage [to reach 10% Brix] with every variety, the variety that is most likely to achieve the required Brix content of 10% is often the one that is open pollinated." Interestingly, processors did not confirm the higher Brix content of OP beetroot varieties. Both assessed the Brix value of OP and hybrid beetroot varieties as more or less comparable. The Brix content is an important quality requirement for both OP and hybrid beetroot varieties. One processor stated that it should not be lower than 8% and the other stated that it should be higher than 10%, for both OP and hybrid beetroot varieties.

### Society level

**Advantage 21:** Several experts and actors mentioned **authenticity, integrity** and **independence from the conventional sector** as an important advantage of organically bred OP varieties.

"If we really take organic farming seriously, then we […] view organic farming as a process. And then we can't start this process by using conventionally bred varieties that have been produced using some kind of technology and have been treated with chemicals." (Expert)

"I don't want to use my money to support conventional breeding and conventional seed production, which I have actually emancipated myself from." (Farmer)

"I don't want to support any conventional structures with the seeds I buy." (Farmer)

„The main reason why we practise organic breeding is that we realise that organic farming has become totally dependent on conventional breeders and seed producers." (Breeder)

**Advantage 22:** Several actors and experts mentioned **GMO-free** as an important advantage of organically bred OP varieties.

"It's very important for us to have a choice. And now again with the new genetic engineering. It's a very nasty arm wrestling match. And they are also trying to get the new genetic engineering into organic farming." (Breeder)

"If we want to keep organic farming GMO-free, then we need a lot more organic breeding in the very foreseeable future." (Breeder)

### 3.3.6 Discussion

A number of field experiments with beetroot for fresh market and the processing industry have been conducted in Germany under organic conditions, including both conventionally bred (and organically multiplied), hybrid beetroot varieties and organically bred, open pollinated (OP) beetroot varieties. In what follows the main results are presented, using the results of Boro F1 and Subeto F1 as representative for hybrid and Robuschka[8] as representative for OP beetroot varieties.

A total of seven field experiments recorded the harvested yield and suggest that the harvested yield of an organically bred OP beetroot variety is 10 to 20% lower than that of a conventionally bred (and organically multiplied), hybrid beetroot variety (Boro and Subeto). This is in line with the findings of this study. Based on the experiments, also the yield stability seems to be slightly better for the hybrid than OP beetroot varieties. Overall the yield varies by around 20%, slightly less for hybrids (17 to 19%) than for OP beetroot varieties (24%) (Perkons, 2018, 2021; Postweiler & Regner, 2020; Rascher & Schubert, 2015; Staub, 2022; Staub & Regner, 2022; Weinheimer & Regner, 2021). Thus, hybrids do perform better, but the difference is rather low in the case of beetroot. A study from the Louis Bolk institute even concludes "that in the context of bio-dynamic farming, OP varieties can have as high yields as F1-hybrids" (Nuijten, 2020, p. 6). And the study suggests that therefore "variety choice can be made much more on the basis of taste and quality, in addition to storability and yield" (Nuijten, 2020, p. 6).

The marketable yield very much differs by market channel or target product (fresh market, processing industry (vaccume packed goods, tinned goods, juice). A total of five field experiments recorded the marketable yield and suggest that it varies between 80 and 95% for both, hybrid and OP beetroot varieties, and is higher if the beetroot goes to the processing industry. Hence, in terms of marketable yield, hybrid and OP beetroot varieties seem comparable (Perkons, 2021; Postweiler & Regner, 2020; Staub & Regner, 2022; Weinheimer & Regner, 2021; Yasaminshirazi et al., 2020).

A total of nine field experiments looked at the susceptibility of beetroot to Cercospora, a leaf spot disease. The results suggest that OP beetroot varieities are less susceptible to Cercospora. This is in line with the findings of the current study. Overall, hybrid beetroot varieties varied between 1 and 6 on a scale from 1 (not susceptible at all) to 9 (very strongly susceptible) and OP between 2 and 4. The susceptibility to Cercospora of OP beetroot varieties was systematically one or two points lower than for hybrid beetroot

[8] The number of field experiments including Gesche are not many and Robuschka is the main OP beetroot variety used for juice processing up to now.

varieties (Hedrich & Rascher, 2019; Mahler, 2017; Perkons, 2016, 2018, 2021; Postweiler & Regner, 2020; Rascher & Schubert, 2015; Staub, 2022; Weinheimer & Regner, 2021).

A total of six field experiments were found that looked at leaf mass. The results suggest that leaf mass is higher for OP beetroot varieties. This is in line with the findings of the current study. On a scale from 1 (very weak) to 9 (very strong), hybrid beetroot varieties ranged between 5 and 7 and OP between 6 and 9. The leaf mass of OP beetroot varieties was systematically one to two points higher than that of hybrid beetroot varieties. Hence, the leaves of OP beetroot varieties seem both, stronger and more healthy (Hedrich & Rascher, 2019; Mahler, 2017; Perkons, 2016, 2018, 2021; Rascher & Schubert, 2015).

A total of nine field experiments looked at the Brix content of the beetroots. The results suggest that the Brix value is higher for OP beetroot varieties. This is in line with the findings of the current study. For hybrid beetroot varieties the Brix content ranged between 8 to 14% and for OP between 10 to 15%. The Brix content of OP beetroot varieties was systematically 1 to 2% higher than that for hybrid beetroot varieties (Hedrich & Rascher, 2019; Mahler, 2017; Perkons, 2016, 2018; Postweiler & Regner, 2020; Staub, 2022; Staub & Regner, 2022; Weinheimer & Regner, 2021; Yasaminshirazi et al., 2020).

Yasaminshirazi et al. (2020) looked at further quality indicators, including the total phenolic content (antioxidants), the Betaxanthin content, the Betacyanin content, and the total dry matter content (TDMC). They also performed a sensory analysis, including the dimensions sweetness, bitterness, earthy flavour, and overall acceptability. The total phenolic content was lower for Robuschka than Boro F1. So were the Betaxanthin and Betacyanin content. The TDMC was higher for Robuschka than Boro F1. Robuschka was perceived sweeter than Boro F1. Regarding bitterness, earthy flavour and overall acceptability both varieties scored the same. Whereas sweetness and bitterness have been found to be positively and negatively correlated with hedonic liking of beetroot, respectively, earthy flavour has been found to be inconsistently associated with hedonic liking (Hanson et al., 2022).

Five studies looked into the uniformity of beetroots, on a scale from 1 (very heterogeneous) to 9 (very homogeneous). The results suggest that OP beetroot varieties are comparable to hybrid beetroot varieties. For both values ranged between 5 and 7. Two studies also included the OP beetroot variety Gesche and evaluated it to be more heterogeneous, values ranging between 4 and 5 (Mahler, 2017; Perkons, 2016, 2018, 2021; Rascher & Schubert, 2015).

A total of nine studies looked at the colour intensity of beetroots on a scale from 1 (very light colour) to 9 (very dark colour). Also regarding this attribute hybrid and OP beetroot varieties seem to be comparable (Hedrich & Rascher, 2019; Mahler, 2017; Perkons, 2016, 2018, 2021; Postweiler & Regner, 2020; Rascher & Schubert, 2015; Staub & Regner, 2022; Weinheimer & Regner, 2021).

Mainly important for the fresh market are the leaves-growth-base-width, the detachement of the root tail and the diameter. The leaves-growth-base-width was looked at in two studies (Mahler, 2017; Rascher & Schubert, 2015), the root tail detachement in eight studies (Hedrich & Rascher, 2019; Mahler, 2017; Perkons, 2016, 2018, 2021; Postweiler & Regner, 2020; Rascher & Schubert, 2015; Staub & Regner, 2022; Weinheimer & Regner, 2021), and the average diameter in three studies (Perkons, 2016; Rascher & Schubert, 2015; Staub, 2022). The leaves-growth-base-width of OP beetroot varieties was assessed to be slightly wider and the root tail more detached. The diameter was evaluated to be comparable.

### 3.3.7 Case study summary

To summarize: This study shows that compared to conventionally bred (and organically multiplied) F1-hybrid beetroot varieties for juice making, organically bred OP beetroot varieties provide the following benefits (Table 15) and costs (Table 16).

**Table 15 Benefits of organically bred OP beetroot cultivars as of case study interviews**

| Type | Stakeholder | Benefits as of case study value chain interviews |
|---|---|---|
| Social/ well-being | Farmers | Give the option to produce own seeds, which gives a good feeling |
| | | Give farmers a higher sense of responsibility |
| | | Give farmers a feeling of security (with regard to climate change). |
| | | Increase farmers' negotiation power |
| | | Make farmers more independant from the conventional sector. |
| | | Increase the collaboration along the value chain: Average agreement among actors of 7 on a scale from 1 to 9 (9 = fully agree). |
| | | Make farmers' work more meaningful and satisfactory |
| Economic | Breeders | Are less costly to breed: About 10 times less costly |
| | | Are a genetic resource (for breeding) |
| | Farmers | Reduction of input costs (OP variety seeds cheaper). |
| | | Are almost as high-yielding: From 10 to 30% lower. |
| | | Give a comparable marketable yield. |
| | | Are more highly valued on the market (if Demeter certified): Price premium of up to 20%. |
| | | Do not result in more time spent on the field. |
| | | Have a stronger leaf mass (which positively correlates with competitive strength against late weeds): Rank 0.5 |

| | | |
|---|---|---|
| | | to 1 point higher on a scale from 1 to 9 (9= very strong). |
| | | Have a good or even better drought tolerance (due to higher genetic diversity, more vigour, and higher leaf mass): Rank 1 point higher on a scale from 1 to 9 (9 = very good). |
| | | Are less susceptible to leaf spots like *Cercospora* (due to higher genetic diversity): Rank 1 point lower on a scale from 1 (1 = not susceptible at all) to 9 |
| | Processors/ consumers | Do not require additional processing effort or equipment. |
| | | Have a systematically higher Brix content: at least 1%. |
| | | Are more vital and therefore perceived as more healthy for human consumption. |
| | Society | make organic actors independent from the conventional sector (increase in authenticity and integrity). |
| | | No patents, no plant variety protection (OP varieties = common good). |
| Ecological | Farmers | Give the option to develop an own locally adapted farmer variety (which can also be an economic benefit, if the variety can be sold at a price premium). |
| | Society | Are more genetically diverse. |
| | | Keep organic farming GMO-Free. |

**Table 16 Costs of organically bred OP beetroot cultivars as of case study interviews**

| Type | Stakeholder | Costs as of case study value chain interviews |
|---|---|---|
| Economic | Farmers | Limited seed availability. |
| | | Lower seed quality (less homogeneous and fast field emergence/ juvenile development, therefore slightly lower weed competitive strength at the beginning – but overall cultivation effort not affected). |
| | | Produce is more heterogeneous in terms of size and shape (but no issue for juice making – marketable yield to juice makers very high). |
| | | Lower yield (yield gap very much dependant on plant species/ cultivar). |

| | | |
|---|---|---|
| | | Lower storability (negative correlation between storability and product quality as confirmed by literature). |
| | Processors | Higher total dry matter content (TDMC) (as confirmed by literature). |

These results show that in the case of beetroot hybrids are not needed and OP varieties provide additional benefits for organic farmers, processors, consumers and society. The main barrier of using organically bred OP beetroot varieties is on the one hand the market's demand for homogeneity and its focus on outer appearance and on the other hand farmers' perception that „only hybrids work“ and that OP varieties do not give a good enough (marketable) yield. Currently, an important barrier is also that only Demeter certified farms can profit from a price premium on OP varieties, at least in the value chain for juice that was the focus of this study.

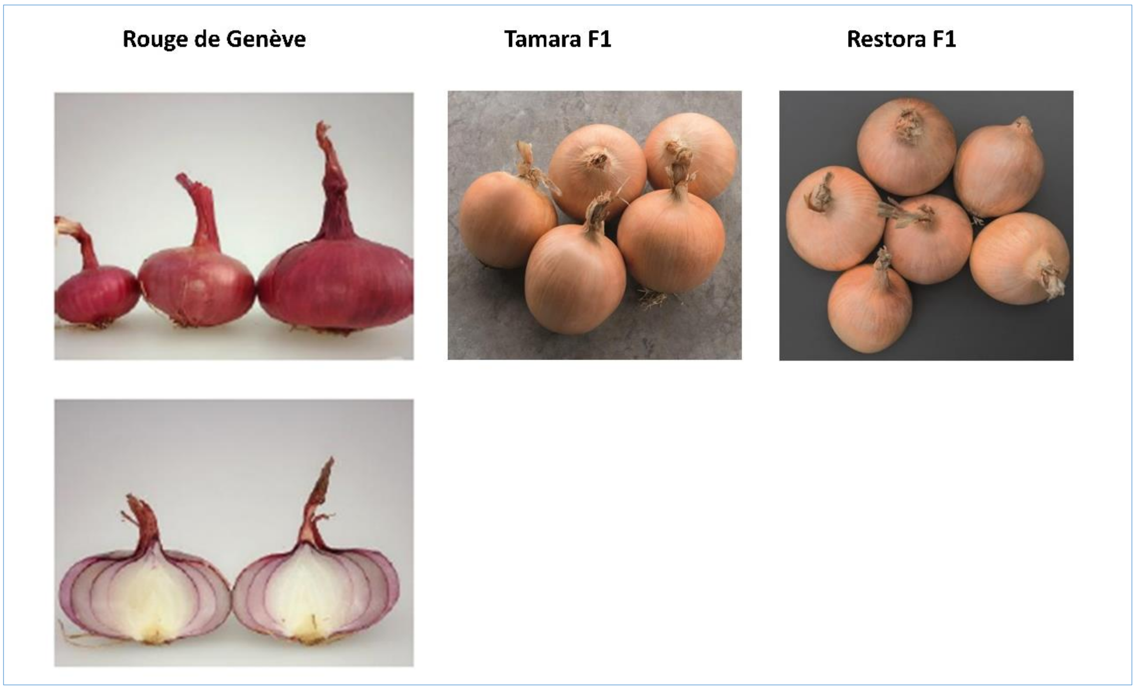
## 3.4 Case study 3: Landrace/ heirloom cultivar in Switzerland

### 3.4.1 Case study description

To identify and evaluate the benefits and costs of landraces/ heirloom cultivars (LR) at different levels of the value chain, we chose unprocessed organic onions in Switzerland as focus product. Benefits and costs of LR onions, specifically the variety ‘Rouge de Genève’ from ProSpecieRara, was evaluated in relation to conventionally bred and organically multiplied F1-hybrid onions (= baseline) in the context of organic farming[9]. Examples for conventionally bred and organically multiplied F1-hybrid onions are ‘Tamara F1’ from Bejo or ‘Restora F1’ from Bejo.

Figure 7: Organic LR and F1-hybrid onions

[9] Landraces/ heirloom cultivars are always open-pollinated. For background information on open-pollinated varieties and F1-hybrids and how they differ, see chapter 3.3.1.




The ‘Rouge de Genève was donated to ProSpecieRara by the Changins gene bank. This strain was then multiplied by F. Lequint in Chêne-Bougeries (Geneva). Also, in Chêne-Bougeries, the Grosjean family multiplied and sold this variety until 2017. Onions of this variety have been on sale at Coop since 2012 (currently not on sale). *Sativa* and *Semences du pays* produce the seeds. The *Artichoke Association* produces the seedlings. Only a small number of market gardeners in Geneva grow the variety. These are small scale growers who produce many different species and varieties. The variety has a good shelf life (at least until December), which could be one of the reasons for its selection, as well as its red colour (Fevre, 2021).

### 3.4.2 Case study specific methodology for the selection and evaluation of indicators

For the identification of suitable indicators, we conducted a workshop in the ‘ecologic neighbourhood’ ‘Les Vergers’ [10] in Meyrin (Geneva, Switzerland) in June 2024. Participants for the workshop were recruited with the support of ProSpecieRara: 2 breeders and seed producers (from *Semences de pays* and ProSpecieRara), 1 farmer, 1 retailer (from La Fève), 1 consumer. We aimed to recruit three farmers and 6 consumers. Unfortunately, this was not possible on the chosen date.

The workshop was promoted using the following advertisement (in French):

English version :

[10] For further information on the ecologic neighbourhood ‘Les Vergers’ see: https://meyrin.ch/fr/ecoquartierlesvergers

Title: Workshop on the benefits of landraces, 1 June, 9.30am to 12pm, Esplanade des Récréations in Meyrin (Geneva, Switzerland)

The ecological and social benefits of landraces are an important puzzle piece in the transition to sustainable food and farming systems. However, many people are not aware of or do not understand landraces, not to mention their benefits. As a result, there is little pressure to increase funding for the conservation of landraces. In this workshop, we want to co-create communication stories to raise public awareness of the benefits and importance of landraces. The workshop is being organised by ProSpecieRara and the Research Institute of Organic Agriculture (FiBL) as part of the Liveseeding (www.liveseeding.eu) and benefits.biobreeding (www.biobreeding.org) projects.

For the workshop, we are looking for people who live in the Les Vergers district and buy vegetables from Ferme des Vergers (or from other participating farmers in the chain). Are you interested in taking part and talking to breeders, farmers and retailers about the benefits of local varieties?

To get involved, please contact: claudia.meier@fibl.org

French version :

Titre : Atelier sur les avantages des Variétés de Pays, 1er juin, 9h30 à 12h, Esplanade des Récréations à Meyrin (Genève, Suisse)

Les avantages écologiques et sociaux des Variétés de Pays constituent une pièce importante du puzzle dans la transition vers des systèmes alimentaires et agricoles durables. Cependant, de nombreuses personnes ne sont pas conscientes ou ne comprennent pas les Variétés de Pays, sans même parler de leurs avantages. Par conséquent, il y a peu de pression pour augmenter le financement de la conservation des Variétés de Pays. Dans cet atelier, nous voulons co-créer des récits de communication pour sensibiliser le grand public aux avantages et à l'importance des Variétés de Pays. L'atelier est organisé par ProSpecieRara et l'Institut de recherche en agriculture biologique (FiBL) dans le cadre des projets Liveseeding (www.liveseeding.eu) et benefits.biobreeding (www.biobreeding.org).

Pour l'atelier, nous recherchons des personnes qui habitent le quartier des Vergers et qui achètent les légumes de la Ferme des Vergers (ou d'autres paysans participatifs de la Filière). Etes-vous intéressé·e pour participer et discuter avec des sélectionneurs, des agriculteurs et des détaillants sur les avantages des Variétés de Pays ?

Pour participer, veuillez contacter : claudia.meier@fibl.org

Table 17 shows the workshop program.

**Table 17: Workshop program**

| What? | Time? |
|---|---|
| Welcome and introduction (10min) | 9.30 – 9.40 |
| What is a landrace (20min) | 9.40 – 10.00 |
| The "value" of landraces (30min):<br>• I enjoy breeding/ growing/ selling/ consuming landraces, because…<br>• I benefit from breeding/ growing/ selling/ consuming landraces, because… | 10.00 – 10.30 |

| | |
|---|---|
| • Landraces will become more relevant in the organic sector, because or if… | |
| What are the costs and benefits of landraces as compared to improved, modern varieties? (60min) | 10.30 – 11.30 |
| Slogans to promote 'Rouge de Genève' (30min) | 11.30 – 12.00 |

At the beginning of the workshop the two projects benefits.biobreeding and LiveSeeding were shortly introduced (including funding source) as well as the organisations organising and facilitating the workshop (FiBL and ProSpecieRara). Participants' were informed about the objectives and aims of both projects, the workshop's structure and objectives.

The overarching question to be answered by the workshop was stated as follows:

- To what extent are landraces 'adapted to the needs of organic farming/ the organic sector'? Or more provocative – for the organic sector: Is it worth it to grow landraces? And if so why? What makes them worth growing? What are the benefits and costs of growing landraces from the point of view of breeding, cultivation, processing, sale, and consumption? Do the benefits exceed the costs?

The aim of the workshop was then stated as follows:

- One goal of today's workshop is to identify the benefits and costs of using landraces in organic farming, i.e. the benefits and costs which need to be considered FROM YOUR PERSPECTIVE AS BREEDER, FARMER, RETAILER, CONSUMER to decide whether it is worth growing landraces.
- Another goal is to use this information for the development of slogans to promote landraces outside of Les Vergers, specifically the onion 'Rouge de Genève', an onion landrace cultivated in the region of Geneva.

Participants were then asked to line up based on their role in the value chain, from breeder to consumer, and quickly state their name and involvement.

In a first discussion round, it was discussed, what a landrace is and how it is communicated to consumers.

In a first warm-up exercise, workshop participants then had to complete the following three sentences in their own words (pictures of the corresponding output can be found in Annex 3):

- I enjoy breeding/ growing/ selling/ consuming landraces, because… (= intrinsic motivation)
- I benefit from breeding/ growing/ selling/ consuming landraces, because… (= extrinsic motivation)
- Landraces will become more relevant in the organic sector, because or if… (= enablers)

In a second exercise, participants discussed the costs and benefits of landraces as compared to improved, modern varieties and wrote the most important costs and benefits on posters prepared for that purpose. There was a total of three posters, each split in two parts, for the annotation of costs and benefits. One poster asked for the benefits and costs in cultivation, one for the benefits and costs regarding profitability and one for any other benefits and costs. To stimulate the discussion, guiding questions were provided (see fourth column in Table 18).

**Table 18: Structure of the posters and guiding questions.**

| | Costs | Benefits | Guiding questions: |
|---|---|---|---|
| **Cultivation** | [OPEN] | [OPEN] | • How does the landrace behave in competition with weeds?<br>• Is the landrace suitable for standard (mechanical) cultivation (hoeing equipment, harvesting methods, etc.)?<br>• Is the landrace well adapted to the regional climate?<br>• Is the landrace suitable for marginal locations (e.g. due to a more efficient uptake of nutrients or water)?<br>• Is the landrace suitable for diversified cultivation systems?<br>• Are landraces more resistant to the most important crop-specific diseases and pests? |
| **Profitability** | [OPEN] | [OPEN] | • How much do landraces and F1-hybrids differ in yield and stability?<br>• How much do landraces and F1-hybrids differ in terms of storability?<br>• Can a higher price be achieved for landraces?<br>• Are landraces qualitatively superior to F1-hybrids (e.g. through an interesting, 'new' appearance? Better flavour? Better nutritional quality? Use for traditional, local dishes, etc.)?<br>• Does the cultivation of landraces strengthen economic resilience? |
| **Other** | [OPEN] | [OPEN] | • Other? |

In a third exercise (brainwriting exercise) workshop participants created slogans to promote the onion landrace 'Rouge de Genève'. The exercise went as follows:

- In a first round, each participant had 2 minutes to write up to three slogans on a sheet of paper. Once time was up, slogans were passed to the person on the right to start the second round. In the second round, each person had again 2 minutes time to further develop the existing slogans. There was a total of three rounds.

### 3.4.3 Results of the workshop

Based on the discussion of the question "what is a landrace", the following definition can be proposed – to be used in the communication with consumers:

- A landrace is the product of a 'non-intentional' plant selection process by farmers in a specific soil and under specific pedoclimatic conditions, resulting in specific properties which are desirable from a farmer's point of view.

Table 19 shows the results of the discussion of costs and benefits of landraces as compared to improved, modern varieties.

**Table 19: Results of exercise 2 – costs and benefits of landraces.**

| | **Costs** | **Benefits** |
|---|---|---|
| **Cultivation** | • Long growth duration/ slower growth<br>• Due to heterogeneity, weeding more difficult<br>• Seeds more expensive | • Due to higher diversity, better local adaptation and more yield stability/ security.<br>• Due to diversity more resistant against diseases and pests/ Cultivated biodiversity leads to fewer plant health risks.<br>• Less water consumption |
| **Profitability** | • For certain cultivars the availability of landraces is limited (e.g. melons, aubergines)<br>• Shorter shelf life (Possibly due to heterogeneity)<br>• Lower yield<br>• Higher cost needs to be justified | • Interest in diversity (among consumers). Each region has different products.<br>• Harvest can be 'scaled' (continuous harvest); possibly advantage for direct, on-farm marketing or gardening<br>• Opportunity to create a story/ narrative, relating to the local history<br>• Opportunity to re-discover ancient/ old recipes. |

| | | |
|---|---|---|
| | • The heterogeneous look/ appearance is rarely an advantage.<br>• No production 'peak' (can be a disadvantage when selling to larger food stores/ in long distribution channels) | • Diversity in terms of taste, nutrients etc.<br>• Better taste (no "water taste")<br>• Better quality<br>• Longer shelf life (because they grow more slowly and absorb less water)<br>• Landraces are suitable for short distribution channels/ local food system (see project "court circuit").<br>• Potential to be sold at higher price (in Geneva: GRTA label[11]) |
| **Society** | • Varieties need to be promoted; awareness needs to be increased | • Certain varieties can be valorised/ promoted by recipes<br>• Food security |

Table 20 shows the results of the brainwriting exercise.

**Table 20: Results of exercise 3 – slogans to promote the onion landrace 'Rouge de Genève' (brainwriting exercise).**

| **Slogans** |
|---|
| French: Le Rouge de Genève? Je rougis de plaisir!<br>English : The Geneva Red? I'm blushing with pleasure! |
| French: Tu rêves, tu salives? Mange un Rouge de Genève!<br>English: Are you dreaming, are you salivating? Eat a Geneva Red! |
| French: Un petit rouge de Genève ?<br>English: A little bit red/ blushed by Geneva? |
| French : Tu vois grenat ? Mange le Rouge de Genève !<br>English : Do you see garnet (red)? Eat a Geneva Red! |

[11] https://www.geneveterroir.ch/fr/marque-de-garantie-grta-info/2443

| |
|---|
| French : Dans Grenat il y a GRTA ! Mange le Rouge de Genève !<br>English : In the garnet (red) there is GRTA! Eat the Geneva Red! |
| French : Rond comme un ballon, grenat comme ton sang !<br>English : Round like a balloon, garnet-coloured like your blood! |
| French : Terre de champions : l’oignon de ta région<br>English : Land of champions: onions from your region |
| French : Oignon de Genève : rouge c’est le must<br>English : Geneva onion: red is the “must have” |
| French : L’oignon de ta région : à rougir de plaisir<br>English : Onions from your region: to blush with pleasure |
| French: L’oignon de ta région : à rugir de plaisir<br>English : The onion of your region: to roar with pleasure |
| French : L’oignon qui donne bonne haleine.<br>English : The onion that gives you good breath. |
| French : Oignon ce jour, Rouge de Genève toujours<br>English : Onion today, the Geneva Red always |
| French : Un petit rouge pour titiller vos papilles ? Testez le Rouge de Genève !<br>English : A little red to tantalise/ tickle/ tease your taste buds? Try the Geneva Red! |
| French : Un local qui sublimera toutes vos recettes<br>English : A local that will bring out the best in all your recipes |
| French : Le Rouge de Genève, un goût aussi intense que sa couleur<br>English : The Geneva Red, a taste as intense as its colour |
| French : Rouge intense - Rouge de Genève, l’oignon qui te titille<br>English: Intense red – the Geneva Red: the onion that titillates/ tickles/ teases you |
| French : Pas un slogan mais une idée de produit : la tresse d’oignons rouge (de Genève) et jaune (de Savoie) |

| |
|---|
| English : Not a slogan, but an idea for a product: braided red (from Geneva) and yellow (from Savoie) onions. |
| French : Soupe à l'oignon ? Oui, mais avec le Rouge de Genève !<br>English : Onion soup? Yes, but with the Geneva Red! |
| French : Cultivé ici, sélectionné ici !<br>English : Grown here, selected here! |
| French : Conçu, cultivé et consommé ici (réf Label GRTA)<br>English : Developed, grown and consumed here (refer to GRTA Label) |
| French : Le meilleur du terroir genevois dans un oignon<br>English : The best of the Geneva territory in one onion |
| French : Le Rouge de Genève, plein de couleur dans ton assiette<br>English : The Geneva Red, plenty of colour on your plate |
| French : Rouge de Genève, pour l'intensité du goût et des couleurs<br>English : The Geneva Red, for intense flavour and colour |
| French: Du goût et de la couleur !<br>English : Taste and colour ! |
| French : De la semence à la tarte à l'oignon en passant par la Ferme des Vergers, totalement local.<br>English : From seed to onion tart, via the Ferme des Vergers, totally local. |
| French : Vous avez souvent acheté un oignon dont la semence est produite à Genève ?<br>English : Have you often bought an onion whose seed was produced in Geneva? |
| French : Force et douceur dans une robe de fête<br>English : Strength and softness in a festive dress |
| French : Piquant comme l'amour, rouge comme le sang<br>English : Pungent as love, red as blood |
| French: Durable et de bonne conservation<br>English : Durable/ tough and long-lasting |

| |
|---|
| French: Il se conserve bien et longtemps, et nous aussi, et la planète<br>English : It lasts for a long time, and so do we, and so does the planet. |
| French : C'est notre terroir qui a choisi son arôme.<br>English : It is our territory that has chosen its aroma. |
| French: Un goût unique grâce à notre terroir<br>English : A unique taste thanks to our territory |

### 3.4.4 List of indicators

Based on the results, we created a list of indicators for the evaluation of costs and benefits of landraces. As in Ficiciyan et al. (2018), indicators were classified into provisioning, regulating, and cultural services. The list of indicators can be found in Annex 3.

As for case study 2, for the assessment of indicators, we either used a specific parameter – if available and feasible for participants to assess – or a 9-point-Likert scale. If it was considered feasible for participants to assess landraces relative to F1-hybrids, a relative scale was used, if not, an absolute scale was used:

Example for a relative scale to compare landraces to F1-hybrids:

1 = significantly lower; 3 = lower; 5 = comparable; 7 = higher; 9 = significantly higher

Example for an absolute scale to rate landraces:

1 = very bad, 3 = bad, 5 = average, 7 = good, 9 = very good

For the assessment of statements, the following 9-point-Likert scale was used:

Scale of agreement to a specific statement:

1 = do not agree at all, 3 = do not agree, 5 = average, 7 = agree, 9 = fully agree, 88 = it depends, 99 = don't know

### 3.4.5 Case study summary

To summarize: This study shows that compared to improved, modern varieties, landraces provide the following benefits and costs.

**Table 21: Costs and benefits of landraces**

| | **Costs** | **Benefits** |
|---|---|---|

| | | |
|---|---|---|
| **Cultivation** | • Long growth duration/ slower growth<br>• Due to heterogeneity, weeding more difficult<br>• Seeds more expensive | • Due to higher diversity, better local adaptation and more yield stability/ security.<br>• Due to diversity more resistant against diseases and pests/ Cultivated biodiversity leads to fewer plant health risks.<br>• Less water consumption |
| **Profitability** | • For certain cultivars the availability of landraces is limited (e.g. melons, aubergines)<br>• Shorter shelf life (Possibly due to heterogeneity)<br>• Lower yield<br>• Higher cost needs to be justified<br>• The heterogeneous look/ appearance is rarely an advantage.<br>• No production 'peak' (can be a disadvantage when selling to larger food stores/ in long distribution channels) | • Interest in diversity (among consumers). Each region has different products.<br>• Harvest can be 'scaled' (continuous harvest); possibly advantage for direct, on-farm marketing or gardening<br>• Opportunity to create a story/ narrative, relating to the local history<br>• Opportunity to re-discover ancient/ old recipes.<br>• Diversity in terms of taste, nutrients etc.<br>• Better taste (no "water taste")<br>• Better quality<br>• Longer shelf life (because they grow more slowly and absorb less water)<br>• Landraces are suitable for short distribution channels/ local food system (see project "court circuit").<br>• Potential to be sold at higher price (in Geneva: GRTA label[12]) |
| **Society** | • Varieties need to be promoted; awareness needs to be increased | • Certain varieties can be valorised/ promoted by recipes<br>• Food security |

[12] https://www.geneveterroir.ch/fr/marque-de-garantie-grta-info/2443

## 4. Publication “Cultivated Biodiversity”

Based on the benefits identified in this work a dissemination publication with the title ”Cultivated Diversity – Organic Seeds for tasty food” has been produced.

The flyer (available in English, German, French and Italian) promotes organic plant breeding as a way to foster sustainability, through local adaption and climate resilience. It highlights the importance of increasing cultivated diversity. In particular, it focuses on the benefits of diversified populations and open pollinated varieties. The flyer encourages consumers to support organic farming by buying locally and advocating for organic seed use. Ultimately, it emphasizes that diverse, organically bred cultivars enhance ecological resilience and taste while supporting local economies. The publication includes the narratives developed in Activity one and represent them in the form of illustrations/infographics.

Link to download the flyer: https://www.biobreeding.org/ressources.html#c39335

## 5. Conclusions

### Benefits of “FURAT Floriddia popolazione” as example of OHM

The results of this study show, that stakeholders working with OHM cultivars see many benefits in using these cultivars, including societal, environmental and economic benefits.

Similarly to the OV case benefits which can be generalized for all OHM cultivars are: actors independence from the conventional sector (and specifically in eaht from the global commodity grain market and concentrated seed market); the ‘common/ public good’ character of OHM due to the absence of patents and plant variety protection; the option of developing locally adapted farmers’ varieties; higher genetic diversity under cultivation; and a guarantee for GMO/NGTs-free products.

The legalisation of OHM marketing by notification and without Plant Variety protection in 2022 prompted in depth discussion in the OHM case, on the relation between IPR, royalties and seed sale and related challenges and opportunities to incentivise the develop new OHM cultivars.

It should be noted here that in open pollinated cultivars can also be the case that no IPR are applied, and the arrangement of the seed sale and pricing should buffer for the provision of seeds as common good to society.

Another outcome of the interviews and the workshops is that populations seem to be particularly well suited for marginal areas and organic conditions as they have the ability to maximize their yield potential through local adaptation. Furthermore, they have both the ability to adapt to climate changes as they occurr, and to absorb climatic shocks (interannual variability), Considering that the impact of climate change will increase in many areas in Europe, deploying more OHM may represent a valuable adaptation strategy for the organic agricultural sector. The factors influencing the distribution of populations are mainly connected to the value chain associated to them. It became clear that processors could have a big influence, since often they act as the link between farmers and consumers. Often farmers that are convinced of the advantages of OHM cultivars, develop their own value chain, either processing and selling the products directly or teaming with other local transformers. This requires a lot of effort, which according to the results of the interviews and the workshops is worth it, mostly becuause it results in higher and more stable revenues for all the actors in the vaue chain. Although nowadays OHM still represents a niche of the organic sector, this case study suggests that there is a lot of potential, as most stakeholders working with populations appear very satisfied, and the available literature shows that they are comparable to uniform lines with relation to their agronomic performances under organinc conditions, whilst bringing some additional advantages linked to their genetic diversity (yield stability, capacity of absorbing climatic shocks, etc.). Nevertheless, the challenges in further developing OHM and its use among farmers should not be neglected and it is clear that a big amount of effort has to be put, including financial resources, knowledge and time. Until recently, the overall conditions within the breeding sector didn't really support the development of populations, however, the new organic regulation created the opportunity to develop OHM. There is already a strong community standing behind the concept and prioritizing ecological and social values that come with using populations, on top of using organic cultivars in general. The necessity to maintain genetic diversity has been universally recognised, and this another good reason to to support OHM at society level.

#### Benefits of open pollinated beetroot varieties as example of Organic Varieties:

The costs and benefits of open pollinated varieties compared to hybrids depend heavily on the plant species or crop. In this study we selected beetroot for the evaluation of costs and benefits of open pollinated varieties in organic farming. The results show that in the case of beetroot, hybrids are not needed. Economic losses at farm-level can be offset by a modest price premium and farmers profit from a better plant health and resilience. There is no economic loss at processing level. In contrast, processors can profit from a higher Brix value, an important quality requirement for juice. At breeding level, there is a substantial cost saving. With the money that is put into a hybrid beetroot variety, organic breeders can develop ten open pollinated beetroot varieties. Benefits which can be generalized for all open pollinated varieties include: organic actors independence from the conventional sector; the 'common/ public good' character of open pollinated varieties due to the absence of patents and plant variety protection; the option of developing locally adapted farmers' varieties; higher genetic diversity; and – if the OP variety is organically bred – a guarantee for GMO-free products. The main barrier of using organically bred OP beetroot varieties is on the one hand the market's demand for homogeneity and its focus on outer appearance and on the other hand farmers' perception that „only hybrids work" and that OP varieties do not give a good enough (marketable) yield. Thus, some effort is required in informing producers about cultivars where open pollinated varieties work well like beetroot and in 'disconnecting' the association between appearance and quality in consumers' heads.

Benefits of landraces:

In this study we selected onions for the evaluation of costs and benefits of landraces in organic farming. Landraces certainly are more heterogeneous than improved, modern varieties. Heterogeneity leads to both costs and benefits. On the cost side there are a lower yield and higher cultivation costs due to slower growth, more complicated weeding, and higher seed prices. In addition, there is a limited availability of landraces for certain cultivars. On the benefit side there are a better local adaptation potential, higher yield stability, better resistance against diseases and pests, decrease in water consumption, the opportunity to create a narrative for consumers, and improved and higher diversity in taste. Shelf life can be shorter due the heterogeneous form or longer, as landraces grow more slowly and absorb less water. The heterogeneity in shape can be a disadvantage if industry and consumers prefer homogeneous produce. The fact that landraces have no production peak can be perceived as disadvantage but also as advantage, as harvest is scalable. Particularly for short value chains/ local food systems the latter can be advantageous.

As for open pollinated varieties, the main barrier of using landraces is the market's demand for homogeneity and the (perceived) lower yield. Thus, effort is required in raising value chain actors awareness of the benefits of landraces.

## 6. References

Baresel, P., Bülow, L., Finckh, M., Frese, L., Knapp, S., Schmidhalter, U., & Weedon, O. (2022). Performance and evolutionary adaptation of heterogeneous wheat populations. *Euphytica*, *218*. https://doi.org/10.1007/s10681-022-03072-2

Bocci, R., Bussi, B., Petitti, M., Franciolini, R., Altavilla, V., Galluzzi, G., Di Luzio, P., Migliorini, P., Spagnolo, S., Floriddia, R., Rosi, G. L., Petacciato, M., Battezzato, V., Albino, A., Faggio, G., Arcostanzo, C., & Ceccarelli, S. (2020). Yield, yield stability and farmers' preferences of evolutionary populations of bread wheat: A dynamic solution to climate change. *European Journal of Agronomy*, *121*, 126156. https://doi.org/10.1016/j.eja.2020.126156

Bohanec, M., Messéan, A., Scatasta, S., Angevin, F., Griffiths, B., Krogh, P. H., Žnidaršič, M., & Džeroski, S. (2008). A qualitative multi-attribute model for economic and ecological assessment of genetically modified crops. *Ecological Modelling*, *215*(1–3), 247–261. https://doi.org/10.1016/j.ecolmodel.2008.02.016

Bosi, S., Negri, L., Fakaros, A., Oliveti, G., & Dinelli, G. (2023). Valorization of wheat production in marginal areas: Farmer-centric experimentation for variety choice and evolutionary population development. *Italian Journal of Agronomy*, *18*(4), Article 4. https://doi.org/10.4081/ija.2023.2210

Burwitz, L. (2019). *Factors influencing the adoption of heterogeneous wheat populations. A qualitative study along the value chain*. University of Kassel.

Ceccarelli, S. (2020, April 6). ICARDA Evolutionary Populations. *Salvatore Ceccarelli*. https://salvatorececcarelli.wordpress.com/2020/04/06/icarda-evolutionary-populations/

Chiffoleau, Y., Dourian, T., Enderli, G., Mattioni, D., Akermann, G., Loconto, A., Galli, F., Emese, G., Perényi, Z., Colombo, L., Massari, S., & Desclaux, D. (2024). Reversing the trend of agrobiodiversity decline by co-developing food chains with consumers: A European survey for change. *Sustainable Production and Consumption*, *46*, 343–354. https://doi.org/10.1016/j.spc.2024.02.032

Fevre, A. (2021). *Analyse descriptive de l'oignon rouge de Genève, une variété traditionnelle*. Haute école du paysage d'ingénierie et d'architecture de Genève.

Ficiciyan, A. M. (2020). *Performance of organic and conventional crop varieties and species mixtures under stress* [Georg-August-University Göttingen]. https://doi.org/10.53846/goediss-48

Hanson, S. J., Dawson, J. C., & Goldman, I. L. (2022). Participatory plant breeding reveals that geosmin concentration is not the central determinant of hedonic liking in table beet. *Euphytica*, *218*(2), 14. https://doi.org/10.1007/s10681-021-02959-w

Hedrich, T., & Rascher, B. (2019). *Versuche im deutschen Gartenbau 2019—ÖKOLOGISCHER GEMÜSEBAU Rote Bete 'Gesche' aus Ökovermehrung liefert sehr gute Erträge bei Frischmarkternte*. Versuchsbetrieb für Gemüsebau Bamberg der Bayerischen Landesanstalt für Weinbau und Gartenbau.

Heiden, C., D'amico, S., Reiter, E., & Flamm, C. (2023). Baking quality of organic heterogeneous material of wheat. *New Plant Breeding Techniques: Myths, Facts and Reality*, 41–44. https://doi.org/10.5281/ZENODO.7875597

Hond-Vaccaro, C. den, Mascher, F., Six, J., & Schöb, C. (2023). *Performance of a winter wheat composite cross population in two temperate agroforestry systems – a Swiss case study*. https://doi.org/10.21203/rs.3.rs-3281511/v1

IFOAM. (2017). *Compatibility of Breeding Techniques in Organic Systems*. IFOAM Organics International. https://www.ifoam.bio/sites/default/files/2020-03/Breeding_position_paper_v01_web_0.pdf

Iocola, I., Angevin, F., Bockstaller, C., Catarino, R., Curran, M., Messéan, A., Schader, C., Stilmant, D., Van Stappen, F., Vanhove, P., Ahnemann, H., Berthomier, J., Colombo, L., Dara Guccione, G., Mérot, E., Palumbo, M., Virzì, N., & Canali, S. (2020). An Actor-Oriented Multi-Criteria Assessment Framework to Support a Transition towards Sustainable Agricultural Systems Based on Crop Diversification. *Sustainability*, *12*(13), 5434. https://doi.org/10.3390/su12135434

Knapp, S., Döring, T. F., Jones, H. E., Snape, J., Wingen, L. U., Wolfe, M. S., Leverington-Waite, M., & Griffiths, S. (2020). Natural Selection Towards Wild-Type in Composite Cross Populations of Winter Wheat. *Frontiers in Plant Science*, *10*. https://doi.org/10.3389/fpls.2019.01757

Kotschi, J., Schrimpf, B., Waters-Bayer, A., & Horneburg, B. (2022). Financing Organic Plant Breeding—New Economic Models for Seed as a Commons. *Sustainability*, *14*(16), 10023. https://doi.org/10.3390/su141610023

Kotschi, J., & Wirz, J. (2015). *Who pays for seeds? Thoughts on financing organic plant breeding*. AGROECOL and Section for Agriculture.

Lammerts van Bueren, E. T., Struik, P. C., van Eekeren, N., & Nuijten, E. (2018). Towards resilience through systems-based plant breeding. A review. *Agronomy for Sustainable Development*, *38*(5), 42. https://doi.org/10.1007/s13593-018-0522-6

Lazzaro, M., Costanzo, A., & Bàrberi, P. (2018). Single *vs* multiple agroecosystem services provided by common wheat cultivar mixtures: Weed suppression, grain yield and quality. *Field Crops Research*, *221*, 277–297. https://doi.org/10.1016/j.fcr.2017.10.006

Lazzaro, M., Winter, E., Schäfer, F., Steiner, E., & Messmer, M. M. (2023). *Financing and governance strategies in organic breeding*. https://www.biobreeding.org/fileadmin/biobreeding/documents/00_BIOBREEDING_SUMMARY_Financing_and_governance_strategies_in_organic_breeding.pdf

Mahler, K. (2017). *Versuche im deutschen Gartenbau 2017 Gemüsebau Rote und Gelbe Bete – Sortenscreening im Frischmarktanbau (ökologisch)*. DLR Rheinpfalz.

Mazé, A., Calabuig Domenech, A., & Goldringer, I. (2021). Commoning the seeds: Alternative models of collective action and open innovation within French peasant seed groups for recreating local knowledge commons. *Agriculture and Human Values*, *38*(2), 541–559. https://doi.org/10.1007/s10460-020-10172-z

Nuijten, E. (2020). *A more holistic approach for breeding: Including quality from a value chain perspective*. Louis Bolk Institute.

Nuijten, E., Messmer, M., & Lammerts Van Bueren, E. (2016). Concepts and Strategies of Organic Plant Breeding in Light of Novel Breeding Techniques. *Sustainability*, *9*(1), 18. https://doi.org/10.3390/su9010018

Perkons, U. (2016). *Versuche im deutschen Gartenbau 2016—Ökologischer Gemüsebau—Rote Bete Sortenversuch*. Versuchszentrum Gartenbau Köln-Auweiler der Landwirtschaftskammer NRW.

Perkons, U. (2018). *Versuche im deutschen Gartenbau 2018 Ökologischer Gemüsebau Rote Bete Sorten*. Versuchszentrum Gartenbau Köln-Auweiler der Landwirtschaftskammer NRW.

Perkons, U. (2021). *Versuche im deutschen Gartenbau 2021—ÖKOLOGISCHER GEMÜSEBAU - Zweites Versuchsjahr: Frühe Pflanzung von Roter Bete*. Versuchszentrum Gartenbau Köln-Auweiler der Landwirtschaftskammer NRW.

Petitti, M. (2021, August 26). *From Cereal Populations to Organic Heterogeneous Material: Success stories and lessons learned in Italy*. EUCARPIA, Rotterdam (NL). https://orgprints.org/id/eprint/42325/1/1%20EUCARPIA_GC_MatteoPetitti_26.8.2021_Final.pdf

Postweiler, K., & Regner, S. (2020). *Versuche im deutschen Gartenbau 2020—ÖKOLOGISCHER GEMÜSEBAU - Rote Bete Sorten `Subeto`, `Monty` und `Pablo`* *erzielten hohe marktfähige Erträge und gleichmäßige Sortierung für die Verarbeitung*. DLR Rheinpfalz.

Rascher, B., & Schubert, W. (2015). *Versuche im deutschen Gartenbau 2015—Ökologischer Gemüsebau Rote Beete 'Boro F1' und 'Robuschka' aus Ökovermehrung liefern sehr gute Erträge*. Versuchsbetrieb für ökologischen Gemüsebau Bamberg der Bayerischen Landesanstalt für Weinbau und Gartenbau.

Rodriguez, C., Dimitrova Mårtensson, L.-M., Zachrison, M., & Carlsson, G. (2021). Sustainability of Diversified Organic Cropping Systems—Challenges Identified by Farmer Interviews and Multi-Criteria Assessments. *Frontiers in Agronomy*, *3*, 698968. https://doi.org/10.3389/fagro.2021.698968

Siegmeier, T., Kluth, J., Weedon, O., Finckh, M., & Moller, D. (2019, March 7). *Produktionsrisiko im ökologischen Winterweizenanbau—Composite Cross-Populationen vs. Liniensorten*. 15. Wissenschaftstagung Ökologischer Landbau.

Spaggiari, M., Marchini, M., Calani, L., Dodi, R., Di Pede, G., Dall'Asta, M., Scazzina, F., Barbieri, A., Righetti, L., Folloni, S., Ranieri, R., Dall'Asta, C., & Galaverna, G. (2022). Evolutionary Wheat Populations in High-Quality Breadmaking as a Tool to Preserve Agri-Food Biodiversity. *Foods*, *11*(4), Article 4. https://doi.org/10.3390/foods11040495

Stadtlander, C. (2005). *Studie zur Sortenvielfalt im Gemüsebau: Untersuchung zur Agrobiodiversität auf der Ebene der Gemüsesorten der EU unter besonderer Berücksichtigung der Züchtungsmethoden sowie Auswirkungen auf die Verfügbarkeit von Gemüsesorten für den biologischen Anbau*. https://orgprints.org/id/eprint/13263/1/stadtlander_2005.pdf

Staub, S. (2022). *Auf der Suche nach den besten Sorten*. DLR Rheinpfalz.

Staub, S., & Regner, S. (2022). *Versuche im deutschen Gartenbau 2022—ÖKOLOGISCHER GEMÜSEBAU - Rote Bete Sorten Anbauversuch für die Verarbeitungsindustrie*. DLR Rheinpfalz.

*Strategies for Organic and Low-Input integrated Breeding and Management*. (n.d.). Strategies for Organic and Low-Input Integrated Breeding and Management. Retrieved 24 October 2023, from http://www.solibam.eu/SOLIBAM/home.html

Vindras-Fouillet, C., Goldringer, I., Frank, G. van, Dewalque, M., Colin, A., Montaz, H., Berthellot, J.-F., Baltassat, R., & Dalmasso, C. (2021). Sensory Analyses and Nutritional Qualities of Wheat Population Varieties Developed by Participatory Breeding. *Agronomy*, *11*(11), Article 11. https://doi.org/10.3390/agronomy11112117

Vollenweider, C., Haak, A., Buhmann, K., Locher, M., Weyermann, V., Schwittek, G., Mascher, F., Finckh, M., & Weedon, O. (2020). *Stability of yield and baking quality parameters of heterogeneous wheat populations*. 71. Tagung der Vereinigung der Pflanzenzüchter und Saatgutkaufleute Österreichs.

Weedon, O., Brumlop, S., Haak, A., Baresel, J. P., Borgen, A., Döring, T., Goldringer, I., Lammerts van Bueren, E., Messmer, M. M., Mikó, P., Nuijten, E., Pearce, B., Wolfe, M., & Finckh, M. R. (2023). High Buffering Potential of Winter Wheat Composite Cross Populations to Rapidly Changing Environmental Conditions. *Agronomy*, *13*(6), Article 6. https://doi.org/10.3390/agronomy13061662

Weedon, O. D., & Finckh, M. R. (2021). Response of wheat composite cross populations to disease and climate variation over 13 generations. *Frontiers of Agricultural Science and Engineering*, *8*(3), Article 3. https://doi.org/10.15302/J-FASE-2021394

Weedon, O., & Finckh, M. (2019). Heterogeneous Winter Wheat Populations Differ in Yield Stability Depending on their Genetic Background and Management System. *Sustainability*, *11*, 6172. https://doi.org/10.3390/su11216172

Weinheimer, S., & Regner, S. (2021). *Versuche im deutschen Gartenbau 2021—ÖKOLOGISCHER GEMÜSEBAU - Rote Bete Sorten Anbauversuch für die Verarbeitungsindustrie*. DLR Rheinpfalz.

Yasaminshirazi, K., Hartung, J., Groenen, R., Heinze, T., Fleck, M., Zikeli, S., & Graeff-Hoenninger, S. (2020). Agronomic Performance of Different Open-Pollinated Beetroot Genotypes Grown Under Organic Farming Conditions. *Agronomy*, *10*(6), 812. https://doi.org/10.3390/agronomy10060812

# 7. Annex I

The last column specifies the actors which were asked to evaluate each indicator (B = breeder, S = advisor from Bingenheimer, F = farmer, P = processor).

**Table 22: List of indicators and statements case study 1: OHM Italy**

| **Indicator** | **Parameter/ Scale** | **Actors** |
|---|---|---|
| **Breeding and seed production** | | |
| Breeding duration of a notified cultivar* *(from crossing/ dynamic mixture to notification/ use for commercial production at farm scale) | Scale: short (5 years), average (10 years), long (more than 10 years) | B |
| Breeding costs per notified cultivar | Scale: 1 = much more than costs of a pure line; 3 = more than a pure line; 5 = the same costs as for a pure line; 7 = less than a pure line; 9 = much less than a pure line | B |
| Seed production: Certified seed needed per ha | dt/ha | B |
| Seed production: Certified seed produced per ha | dt/ha | B |

| | | |
|---|---|---|
| Average amount of certified OHM seed sold in the last 5 years | dt/year | B |
| Average demand of certified OHM seed in the last 5 years | dt/year | B |
| Selling price for certified OHM seed | €/dt | B |
| **On farm** | | |
| Perceived fair price fo certified OHM seed | €/dt | F |
| Amount of seed needed per ha for wheat cultivation | dt/ha | F |
| During the last 5 years: amount of seed saved on farm | dt/year | F |
| During the last 5 years: amount of seed saved on farm per ha of cultivated wheat | % | F |
| During the last 5 years: bought seed (in addition to farm-saved seed) per ha of cultivated wheat | % | F |
| **"The quality of seed saved on farm is worse than the quality of certified seed."** | Scale (1 = not agree at all, 3 = do not agree, 5 = average, 7 = agree, 9 = fully agree, 88 = it depends, 99 = don't know) | F |
| When saving on farm: costs for seed production*<br>*Relates to hours of work for seed cleaning and other activities in the field | €/dt | F |
| Number of times to go to the field | | F |
| Average time spent on the field per time go to the field | h/ha | F |
| Area needed to store raw material | m^2/dt | F, P |
| Costs to store raw material (incl. fixed and variable costs)*<br>*How much rent would you pay to store 1 dt of wheat? | €/dt | |
| Storability of raw material without losing quality | months | F, P |
| Area needed to store seed | m^2/dt | B, F |
| Costs to store seed (incl. fixed and variable costs)*<br>*How much rent would you pay to store 1 dt of seed? | €/dt | B, F |
| Labour input for seed cleaning | h/dt | B, F |
| Farm-saved OHM seed compared to bought OHM seed: vulnerability to seedborne diseases | Scale (1 = much more vulnerable, 3 = more vulnerable, 5 = comparable to pure line, 7 = less vulnerable, 9 = much less vulnerable) | B, F |

| | | |
|---|---|---|
| OHM seed compared to pure line seed: vulnerability to seedborne diseases | Scale (1 = much more vulnerable, 3 = more vulnerable, 5 = comparable to pure line, 7 = less vulnerable, 9 = much less vulnerable) | B, F |
| **Productivity** | | |
| Yield potential: Harvested yield under optimal growing conditions (with standard humidity = 14%) | t/ha | B, F |
| Adaptation to location | Scale: 1 = much lower than in a pure line; 3 = low than in a pure line; 5 = the same; 7 = higher than a pure line; 9 = much higher | B, F |
| **"The adaptation to the location over the years goes hand in hand with a decline of genetic diversity within the OHM cultivar."** | Scale (1 = not agree at all, 3 = do not agree, 5 = average, 7 = agree, 9 = fully agree, 88 = it depends, 99 = don't know) | B, F |
| Buffering effect against climatic extremes | Scale: 1 = much lower than in a pure line; 3 = low than in a pure line; 5 = the same; 7 = higher than a pure line; 9 = much higher | B, F |
| **"The first question when you go to the bank and ask for a possibility to invest your money with the lowest possible risk, they will tell you to diversify your portfolio. OHM is nothing else than the same strategy applied to agriculture"** | Scale (1 = not agree at all, 3 = do not agree, 5 = average, 7 = agree, 9 = fully agree, 88 = it depends, 99 = don't know) | B, F |
| Nutrient use efficiency*<br>*Ability to deal with nutrient poor soils | Scale (1 = very bad, 3 = bad, 5 = average, 7 = good, 9 = very good) | B, F |
| Water use efficiency*<br>*Ability to deal with water scarcity | Scale (1 = very bad, 3 = bad, 5 = average, 7 = good, 9 = very good) | B, F |
| Yield range over the last 5 years | t/ha (range: min, average, max) | B, F |
| Yield compared to the location's yield potential over the last 5 years | % (range: min, average, max) | B, F |
| Yield suitable for human consumption in the last 5 years | % of harvested yield (range: min, average, max) | F |
| **Processing** | | |
| Grain: Purchase price | €/kg or t | P |

| | | |
|---|---|---|
| Grain: expected protein content | Scale: 1 = much lower than in a pure line; 3 = low than in a pure line; 5 = the same; 7 = higher than a pure line; 9 = much higher | P |
| Grain: expected gluten content | Scale: 1 = much lower than in a pure line; 3 = low than in a pure line; 5 = the same; 7 = higher than a pure line; 9 = much higher | P |
| Flour: purchase price | €/kg or t | |
| Flour: expected protein content | Scale: 1 = much lower than in a pure line; 3 = low than in a pure line; 5 = the same; 7 = higher than a pure line; 9 = much higher | P |
| Flour: expected gluten content | Scale: 1 = much lower than in a pure line; 3 = low than in a pure line; 5 = the same; 7 = higher than a pure line; 9 = much higher | P |
| Flour: expected w value | Scale: 1 = much lower than in a pure line; 3 = low than in a pure line; 5 = the same; 7 = higher than a pure line; 9 = much higher | P |
| Flour: Perceived baking quality | Scale (1 = much worse than a pure line, 3 = worse than a pure line, 5 = the same as a pure line, 7 = better than a pure line, 9 = much better than a pure line) | P |
| Flour: Variability of baking quality between batches | Scale (1 = very variable, 3 = variable, 5 = average, 7 = little variable, 9 = not variable at all) | P |
| **"It's way easier as a processor to work with uniformity (instead of heterogeneity). That's clear."** | **Scale (1 = not agree at all, 3 = do not agree, 5 = average, 7 = agree, 9 = fully agree, 88 = it depends, 99 = don't know)** | P |
| Bread: expected gluten content | Scale: 1 = much lower than in a pure line; 3 = low than in a pure line; 5 = the same; 7 = higher than a pure line; 9 = much higher | P |
| Bread: expected nutritional value | Scale (1 = very bad, 3 = bad, 5 = average, 7 = good, 9 = very good) | P |
| Bread: taste | Scale (1 = very bad, 3 = bad, 5 = average, 7 = good, 9 = very good) | F, P |
| Bread: expected shelf life | days | F, P |
| Bread: selling price | €/kg | P |

| | | |
|---|---|---|
| **"Even if FURAT is a bread wheat cultivar, it can be used to make other products like pasta or beer."** | **Scale (1 = not agree at all, 3 = do not agree, 5 = average, 7 = agree, 9 = fully agree, 88 = it depends, 99 = don't know)** | P |
| **Value chain and society** | | |
| Required knowledge for cultivating OHM wheat | Scale (1 = very little, 3 = little, 5 = average, 7 = much, 9 = very much) | F |
| Required knowledge for processing OHM wheat | Scale (1 = very little, 3 = little, 5 = average, 7 = much, 9 = very much) | F, P |
| Perceived independence of value chain from global seed market | Scale (1 = very little, 3 = little, 5 = average, 7 = much, 9 = very much) | B, F, P |
| Perceived workload | Scale (1 = very little, 3 = little, 5 = average, 7 = much, 9 = very much) | B, F P |
| **"One positive point of OHM is that there are no patents, there is no Plant variety protection and the cultivars are available to the public"** | Scale (1 = not agree at all, 3 = do not agree, 5 = average, 7 = agree, 9 = fully agree, 88 = it depends, 99 = don't know) | B, F, P |
| **"OHM cultivars strengthen cooperation along the value chain."** | Scale (1 = not agree at all, 3 = do not agree, 5 = average, 7 = agree, 9 = fully agree, 88 = it depends, 99 = don't know) | B, F, P |
| **"OHM cultivars contribute to food security."** | Scale (1 = not agree at all, 3 = do not agree, 5 = average, 7 = agree, 9 = fully agree, 88 = it depends, 99 = don't know) | B, F, P |
| **"The genetic diversity within one cultivar itself brings an added value."** | Scale (1 = not agree at all, 3 = do not agree, 5 = average, 7 = agree, 9 = fully agree, 88 = it depends, 99 = don't know) | B, F, P |
| **"OHM cultivars have advantages that cannot be quantified"** | Scale (1 = not agree at all, 3 = do not agree, 5 = average, 7 = agree, 9 = fully agree, 88 = it depends, 99 = don't know) | B, F, P |
| **"The nature of OHM is not compatible with the conventional market."** | Scale (1 = not agree at all, 3 = do not agree, 5 = average, 7 = agree, 9 = fully agree, 88 = it depends, 99 = don't know) | B, F, P |
| **"The use/development of OHM implies that there is only natural selection."** | Scale (1 = not agree at all, 3 = do not agree, 5 = average, 7 = agree, 9 = fully agree, 88 = it depends, 99 = don't know) | B, F, P |
| **"When using/developing OHM cultivars, selection by the breeder/farmer is possible."** | Scale (1 = not agree at all, 3 = do not agree, 5 = average, 7 = agree, 9 = fully agree, 88 = it depends, 99 = don't know) | B, F, P |
| **"When using/developing OHM cultivars, selection by the breeder/farmer is needed."** | Scale (1 = not agree at all, 3 = do not agree, 5 = average, 7 = agree, 9 = fully agree, 88 = it depends, 99 = don't know) | B, F, P |

# 8. Annex 2

The last column specifies the actors which were asked to evaluate each indicator (B = breeder, S = advisor from Bingenheimer, F = farmer, P = processor).

Importantly: Not for all benefits and costs a meaningful indicator could be identified. For instance, to assess the value of OP varieties as genetic resource for further breeding, a simple indicator was not considered meaningful. Methods like contingent valuation from the field of Environmental Economics would be more suitable for quantification in that case.

**Table 23: List of indicators and statements case study 2: OV beetroot Germany**

| Nr. | Question/ Statement/ Indicator | Question type/ Parameter | Actors |
|---|---|---|---|
| 1 | Breeding/ seed production level | | |
| 1.01 | Breeding targets | Open question | B |
| 1.02 | Place of breeding | Open question | B |
| 1.03 | Breeding Duration | Years | B |
| 1.04 | Breeding costs | EUR/variety | B |
| 1.05 | Costs for maintenance breeding | EUR/variety | B |
| 1.06 | Seed quality of OP beetroot compared to hybrid varieties | Scale (1 = no, significantly lower, 3 = no, lower, 5 = yes, comparable, 7 = no, higher, 9 = no, significantly higher, 88 = depends, 99 = don't know) | S |
| 1.07 | "The amount of seed demanded of OP varieties exceeds the amount of seed produced." | Scale (1 = not agree at all, 3 = do not agree, 5 = average, 7 = agree, 9 = fully agree, 88 = it depends, 99 = don't know) | S |
| 1.08 | Quantity of seed of OP beetroot varieties sold | Kg/year | S |
| 2 | Cultivation level | | |
| 2.01 | Location of the farm | Open question | F |
| 2.02 | Certification | Open question | F |
| 2.03 | Type of soil | Open question | F |
| 2.04 | Would you say the conditions on your farm are optimal or rather difficult for growing | Scale (1 = Very difficult growing conditions, 3 = Difficult growing conditions, 5 = Average, 7 = | F |

| | | | |
|---|---|---|---|
| | beetroot (e.g. nutrient-poor soils, long dry periods, long rainy season, disease pressure)? | Good growing conditions, 9 = Optimal growing conditions, 99 = Don't know/can't judge) | |
| 2.05 | Irrigation | Yes/No | F |
| 2.06 | Cultivated beetroot varieties | Open question | F |
| 2.07 | What motivates you/organic farmers to grow an OP beetroot variety such as Robuschka or Gesche? Why do you/ organic farmers grow an OP variety instead of a hybrid variety? | Open question | B, S, F, P |
| 2.08 | Since when do you cultivate the beetroot variety on your farm? | Year | F |
| 2.09 | For individual farm: Area/ Area share, on which beetroot variety is cultivated | %/ ha | F |
| 2.10 | Buyer of each variety | Open question | F |
| 2.11 | Target market | Open question | F |
| 2.12 | Planned plant/ stocking density | plants/m2/year | S, F |
| 2.13 | Quantity of seeds for planned plant/ stocking density | units/ha<br>(1 unit = 100'000 seeds) | S, F |
| 2.14 | Seed producer/ seller | Open question | F |
| 2.15 | Seed price | EUR/unit<br>(1 unit = 100'000 seeds) | S, F |
| 2.16 | What needs/ expectations do organic farmers have regarding beetroot varieties when they grow them for juice producers? | Open question | B, F |
| 2.17 | "[OP varieties] are adapted to the needs of organic farmers who grow beetroot for juice producers such as Voelkel or Gesa." | Scale (1 = not agree at all, 3 = do not agree, 5 = average, 7 = agree, 9 = fully agree, 88 = it depends, 99 = don't know) | B, S, F |
| 2.18 | Proportion of organic farmers who use organically bred, OP beetroot varieties. | % | B, S, F |
| 2.19 | Proportion of organic farmers who use organically bred, OP | % | B, S, F |

| | | | |
|---|---|---|---|
| | beetroot varieties and obtain the seed on their own farm. | | |
| 2.20 | Feasability of producing good quality seed on farm | Scale (1 = very easy/ very low costs, 3 = easy/ low costs, 5 = average, 7 = hard/ high costs, 9 = very hard/ very high costs) | B, S, F |
| 2.21 | Germination capacity | % | B, S, F |
| 2.22 | Uniformity of field emergence | Scale (1 = not uniform at all, 3 = not uniform, 5 = medium, 7 = uniform, 9 = very uniform) | B, S, F |
| 2.23 | "The harvested yield of [OP varieties] is comparable to the harvested yield of [hybrids]." | Scale (1 = no, significantly lower, 3 = no, lower, 5 = yes, comparable, 7 = no, higher, 9 = no, significantly higher, 88 = depends, 99 = don't know) | B, S, F |
| 2.24 | "The yield stability of [OP varieties] is comparable to the yield stability of [hybrids]." | Scale (1 = no, significantly lower, 3 = no, lower, 5 = yes, comparable, 7 = no, higher, 9 = no, significantly higher, 88 = depends, 99 = don't know) | B, S, F |
| 2.25 | (Harvested) yield and stability: (Harvested) yield achieved in the last 3 to 5 years on your farm - average, minimum, maximum<br><br>*Note: fresh weight, after the leaves are removed.* | tonnes/ha/year | B, S, F |
| 2.26 | "The marketable yield of [OP varieties] is comparable to the marketable yield of [hybrids]." | Scale (1 = no, significantly lower, 3 = no, lower, 5 = yes, comparable, 7 = no, higher, 9 = no, significantly higher, 88 = depends, 99 = don't know) | B, S, F |
| 2.27 | Marketable yield share and stability:<br>(Harvested) yield share marketable to juice processor in the last 3 to 5 years on your farm - average, minimum, maximum | % | B, S, F |
| 2.28 | "The cultivation worthiness/ economic viability of [OP varieties] is comparable to the cultivation worthiness/ economic viability of [hybrids]." | Scale (1 = no, significantly worse, 3 = no, worse, 5 = yes, comparable, 7 = no, better, 9 = no, significantly better, 88 = depends, 99 = don't know) | B, S, F |

| | | | |
|---|---|---|---|
| 2.29 | (Optimal) Timespan of growing period:<br>Number of months from seed bed preparation and sowing to harvest | Number of days | B, S, F |
| 2.30 | "The time spent on field during the growing period of [OP varieties] is the same as the time spent on field during the growing period of [hybrids]." | Scale (1 = no, significantly less, 3 = no, less, 5 = yes, comparable, 7 = no, more, 9 = no, significantly more, 88 = depends, 99 = don't know) | S, F |
| 2.31 | Storability:<br>Number of months yield can be stored without incurring major losses. | Number of months | B, S, F |
| 2.32 | "[OP varieties] adapted very well to the growing/ cultivation conditions on my farm." | Scale (1 = not agree at all, 3 = do not agree, 5 = average, 7 = agree, 9 = fully agree, 88 = it depends, 99 = don't know/ cannot judge) | F |
| 2.33 | Suitability for difficult growing/ cultivation conditions (such as no irrigation options, heavy soils, clayey soils...) | Scale (1 = very bad, 3 = bad, 5 = average, 7 = good, 9 = very good, 99 = don't know/ cannot judge) | F |
| 2.34 | "[OP varieties] are just as suitable for cultivation on nutrient-poor soils as [hybrids]." | Scale (1 = no, significantly less suitable, 3 = no, less suitable, 5 = yes, comparable, 7 = no, more suitable, 9 = no, significantly more suitable, 88 = depends, 99 = don't know) | B, S, F |
| 2.35 | Suitability for cultivation on nutrient-poor soils. | Scale (1 = very bad, 3 = bad, 5 = average, 7 = good, 9 = very good, 99 = don't know/ cannot judge) | F |
| 2.36 | "[OP varieties] last just as long as [hybrids] when it's dry for a longer period of time (drought resistance)." | Scale (1 = no, significantly less long, 3 = no, less long, 5 = yes, equally long, 7 = no, longer, 9 = no, significantly longer, 88 = depends, 99 = don't know) | B, S, F |
| 2.37 | Tolerance/ Resistance to drought | Scale (1 = very bad, 3 = bad, 5 = average, 7 = good, 9 = very good, 99 = don't know/ cannot judge) | F |
| 2.38 | "[OP varieties] stay healthy just as long as [hybrids]." | Scale (1 = no, significantly less long, 3 = no, less long, 5 = yes, | B, S, F |

| | | | |
|---|---|---|---|
| | | equally long, 7 = no, longer, 9 = no, significantly longer, 88 = depends, 99 = don't know) | |
| 2.39 | Susceptibility to cercospora | Scale (1 = not susceptible at all (no leaf spots), 3 = little susceptible, 5 = average, 7 = strongly susceptible, 9 = very strongly susceptible) | B, S, F |
| 2.40 | "The weed competitive strength of [OP varieties] is comparable to the weed competitive strength of [hybrids]." | Scale (1 = no, significantly lower, 3 = no, lower, 5 = yes, comparable, 7 = no, higher, 9 = no, significantly higher, 88 = depends, 99 = don't know) | B, S, F |
| 2.41 | Competitive power/strength against weeds (Weed suppression & tolerance) | Scale (1= very weak (very low leaf mass), 3 = weak, 5 = average, 7 = strong, 9 = very strong) | F |
| 2.42 | "Organically bred, open pollinated varieties strengthen farms' autonomy/ independence." | Scale (1 = not agree at all, 3 = do not agree, 5 = average, 7 = agree, 9 = fully agree, 88 = it depends, 99 = don't know) | B, S, F |
| 2.43 | "Organically bred, open pollinated varieties strengthen farms' [OPEN]." | Open question | B, S, F |
| 3 | Processing level | | |
| 3.01 | Processed beetroot varieties | Open question | P |
| 3.02 | Certification of processed beetroot varieties | Open question | P |
| 3.03 | Product claim for OP varieties | Open question | P |
| 3.04 | Product brand for the sale of juice made from OP beetroot varieties | Open question | P |
| 3.05 | Number of farms and other entities (producer association, traders) from which beetroot is sourced | Number | P |
| 3.06 | Processed quantity | Tons/ year | P |
| 3.07 | Regions/ countries from which beetroot is sourced | Open question | P |
| 3.08 | Quality requirements for organic farmers? | Open question | B, F, P |
| 3.09 | Price paid by the juice processor for marketable yield | EUR/tonne ODER EUR/kg | F, P |

| | | | |
|---|---|---|---|
| 3.10 | Price of juice (not bottled) | EUR/litre | P |
| 3.11 | Price of end product containing OP beetroot varieties (bottled) | EUR/litre | P |
| 3.12 | Price premium consumers pay for juice from OP beetroot varieties as compared to hybrids | EUR/litre | P |
| 3.13 | Processing effort | Scale (1 = very much lower for OP, 3 = lower for OP, 5 = same, 7 = higher for OP, 9 = very much higher for OP) | P |
| 3.14 | Brix content – raw material | Degrees of Brix (%) | B, S, F, P |
| 3.15 | Brix value required by the processor (of the raw material) | Degrees of Brix (%) | F, P |
| 3.16 | Uniformity – raw material | Scale (1 = very heterogeneous, 3 = heterogeneous 5 = average, 7 = homogeneous 9 = very homogeneous) | B, S, F, P |
| 3.17 | Uniformity required by the processor (of the raw material) | | P |
| 3.18 | Total dry matter content – raw material (the higher the TDM content, the worse the juice yield. | % | P |
| 3.19 | Inner colouring | Scale (1 = very light colour/ very many light rings, 3 = light colour/ many light rings, 5 = medium, 7 = dark colour/ few light rings, 9 = very dark colour/ no light rings) | P |
| 3.20 | Sensory quality - bitterness | Scale (1 = very low intensity, 3 = low intensity, 5 = medium intensity, 7 = high intensity, 9 = very high intensity) | P |
| 3.21 | Sensory quality – earthy taste | Scale (1 = very low intensity, 3 = low intensity, 5 = medium intensity, 7 = high intensity, 9 = very high intensity) | P |
| 3.22 | Motivation to process OP varieties | Open question | P |
| 3.23 | Sales development of OP variety juice in the last 5 to 10 years | Open question | P |
| 4 | Value chain/ society level | | |

| | | | |
|---|---|---|---|
| 4.01 | "Organically bred, OP varieties strengthen cooperation along the value chain." | Scale (1 = not agree at all, 3 = do not agree, 5 = average, 7 = agree, 9 = fully agree, 88 = it depends, 99 = don't know) | B, S, F |
| 4.02 | Number of OP red beet varieties in the EU | Number | B, S, F |
| 4.03 | Number of beetroot hybrids in the EU | Number | B, S, F |
| 4.04 | Tax money used for genetic engineering in animal and plant breeding | EUR | B |
| 4.05 | Tax money used for organic animal and plant breeding | EUR | B |
| 4.06 | Share of tax money used for organic animal and plant breeding (as of total tax money used for animal and plant breeding) | % | B |
| 4.07 | Now you have the opportunity to express your wishes to breeders, seed producers and processors. | Open question | B, S, F |

# 9. Annex 3

**Table 24: List of indicators and statements case study 3: Landraces Switzerland**

| Nr | Level | Indicator | Parameter |
|---|---|---|---|
| 1 | Provisioning services (farmer) | "The effort required for the development of a locally adapted variety using landraces is comparable to the effort required using hybrids." | Scale (1 = no, significantly lower, 3 = no, lower, 5 = yes, comparable, 7 = no, higher, 9 = no, significantly higher, 88 = depends, 99 = don't know) |
| 2 | | Planned plant/ stocking density | plants/m2/year |
| 3 | | Quantity of seeds for planned plant/ stocking density | units/ha (1 unit = 100'000 seeds) |
| 4 | | Seed price | EUR/unit (1 unit = 100'000 seeds) |

| | | | |
|---|---|---|---|
| 5 | | Germination capacity | % |
| 6 | | Uniformity of field emergence | Scale (1 = not uniform at all, 3 = not uniform, 5 = medium, 7 = uniform, 9 = very uniform) |
| 7 | | (Harvested) yield and stability: (Harvested) yield achieved in the last 3 to 5 years on your farm - average, minimum, maximum | tonnes/ha/year |
| 8 | | Marketable yield share and stability: Marketable yield share in the last 3 to 5 years on your farm - average, minimum, maximum | % |
| 9 | | (Optimal) Timespan of growing period: Number of days from seed bed preparation and sowing to harvest (growth duration) | Number of days |
| 10 | | "The time spent on field during the growing period of landraces is the same as the time spent on field during the growing period of hybrids." | Scale (1 = no, significantly less, 3 = no, less, 5 = yes, comparable, 7 = no, more, 9 = no, significantly more, 88 = depends, 99 = don't know) |
| 11 | | "The time spent for weeding is the same for landraces as for hybrids." | Scale (1 = no, significantly less, 3 = no, less, 5 = yes, comparable, 7 = no, more, 9 = no, significantly more, 88 = depends, 99 = don't know) |
| 12 | | Storability: Number of months yield can be stored without incurring major losses. | Number of months |
| 13 | | "Landraces are adapted very well to the growing/ cultivation conditions of small producers." | Scale (1 = not agree at all, 3 = do not agree, 5 = average, 7 = agree, |

| | | | |
|---|---|---|---|
| | | | 9 = fully agree, 88 = it depends, 99 = don't know/ cannot judge) |
| 14 | Regulating services (environment) | "Landraces last just as long as hybrids when it's dry for a longer period of time (drought resistance)." | Scale (1 = no, significantly less long, 3 = no, less long, 5 = yes, equally long, 7 = no, longer, 9 = no, significantly longer, 88 = depends, 99 = don't know) |
| 15 | | Tolerance/ Resistance to drought | Scale (1 = very bad, 3 = bad, 5 = average, 7 = good, 9 = very good, 99 = don't know/ cannot judge) |
| 16 | | "Landraces stay healthy just as long as hybrids." | Scale (1 = no, significantly less long, 3 = no, less long, 5 = yes, equally long, 7 = no, longer, 9 = no, significantly longer, 88 = depends, 99 = don't know) |
| 17 | | Susceptibility to fungus diseases | Scale (1 = not susceptible at all, 3 = little susceptible, 5 = average, 7 = strongly susceptible, 9 = very strongly susceptible) |
| 18 | | "The weed competitive strength of landraces is comparable to the weed competitive strength of hybrids." | Scale (1 = no, significantly lower, 3 = no, lower, 5 = yes, comparable, 7 = no, higher, 9 = no, significantly higher, 88 = depends, 99 = don't know) |
| 19 | | Competitive power/strength against weeds (Weed suppression & tolerance) | Scale (1= very weak (very low leaf mass), 3 = weak, 5 = average, 7 = strong, 9 = very strong) |
| 20 | Cultural services (society) | Price premium consumers pay for landraces as compared to hybrids | EUR/kg |
| 21 | | Uniformity – raw material | Scale (1 = very heterogeneous, 3 = heterogeneous 5 = average, 7 = homogeneous 9 = very homogeneous) |
| 22 | | Total dry matter content – raw material | % |

| | | | |
|---|---|---|---|
| 23 | | "The nutritional value of landraces is comparable to the nutritional value of hybrids." | Scale (1 = no, significantly lower, 3 = no, lower, 5 = yes, comparable, 7 = no, higher, 9 = no, significantly higher, 88 = depends, 99 = don't know) |
| 24 | | Sensory quality – sweetness | Scale (1 = very low intensity, 3 = low intensity, 5 = medium intensity, 7 = high intensity, 9 = very high intensity) |
| 25 | | Sensory quality – bitterness | Scale (1 = very low intensity, 3 = low intensity, 5 = medium intensity, 7 = high intensity, 9 = very high intensity) |
| 26 | | Sensory quality – spiciness/ Umami | Scale (1 = very low intensity, 3 = low intensity, 5 = medium intensity, 7 = high intensity, 9 = very high intensity) |
| 27 | | Traditional, local dishes made with the landrace | [OPEN QUESTION] |
| 28 | | "The recognizability (= recognition value) of landraces is comparable to the recognizability of hybrids." | Scale (1 = no, significantly lower, 3 = no, lower, 5 = yes, comparable, 7 = no, higher, 9 = no, significantly higher, 88 = depends, 99 = don't know) |