



Guidelines for Quality and Diversity Management of OHM Seed

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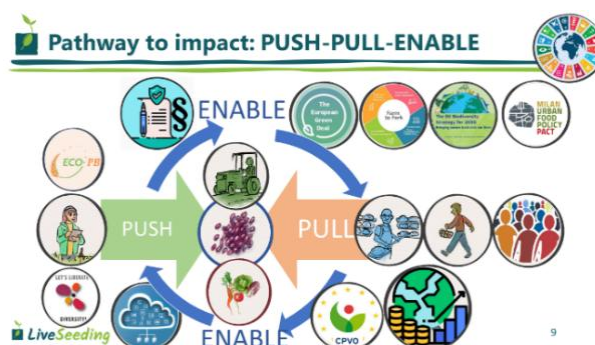
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LiveSeeding - Organic seed and plant breeding to accelerate sustainable and diverse food systems in Europe is a 4-year Innovation Action funded by the European Union, the Swiss State Secretariat for Education, Research and Innovation (SERI) and UK Research and Innovation (UKRI). The project started in October 2022 and brings together 37 organisations operating in 16 European countries. LiveSeeding provides science-based evidence and best practice solutions to help achieve 100 % organic seed.

LiveSeeding contributes to the transition towards environmentally-friendly, climate-neutral, healthy and fair food systems through a **PUSH-PULL-ENABLE strategy** to

- enhance the availability and adequacy of organic seeds of cultivars appropriate to organic farming (PUSH),
- increase and stabilise the market demand for organic seeds of cultivars appropriate to organic farming (PULL),
- foster an enabling policy and regulatory environment where both demand and supply can harmoniously and productively negotiate without irrelevant constraints due to legal restrictions and/or regulatory fragmentation (ENABLE).



LiveSeeding addresses the topics in a **holistic multi-actor, multi-stakeholder, participatory approach** involving stakeholders along the value chain in 17 local **Living Labs** (LLs) and 3 established networks of organic breeders (**ECO-PB**), seed savers (**ECLLD**) and Milan Urban Food Policy Pact (**MUFPP**). 15 European countries cover the different pedoclimatic zones and socio-economic contexts, including countries with a low level of development in organic seed and breeding in East and South Europe.

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List of abbreviations

API	Application Programming Interface
BRAPI	Breeding Application Programming Interface
CCP	Composite Cross Population
DP	Dynamic Population
DUS	Distinctness, Uniformity, Stability
EPB	Evolutionary Participatory Breeding
FS	Farmers' Selection
ISTA	International Seed Testing Association
OHM	Organic Heterogeneous Material
PA	Practice Abstract
PRM	Plant Reproductive Material
VCU	Value for Cultivation and Use

Summary

Organic Heterogeneous Material (OHM) constitutes a novel cultivar category characterised by a high level of genetic and phenotypic diversity and a dynamic population structure, which may contribute to increased resilience to climatic variability. OHM was introduced under Regulation (EU) 2018/848 on organic production and labelling of organic products and must be produced in accordance with organic farming requirements. Detailed provisions governing the production and marketing of OHM are laid down in Commission Delegated Regulation (EU) 2021/1189. The practical implementation of OHM in seed production is still in its initial phase. Deliverable 3.3 identifies key elements of quality and diversity management for OHM seed and provides practical examples and guidelines for OHM seed propagators.

OHM may be placed on the market following a notification procedure to the competent authority. Since the regulatory introduction of OHM, several notified materials have become available for cultivation in both arable and vegetable crop categories, and production activities have been initiated in multiple European countries. However, to date, limited consolidated information and practical experience are available regarding the seed propagation of this cultivar category.

The objective of this deliverable is to provide background information and practical guidance on the seed quality and diversity management of OHM, drawing on scientific literature and the experience of relevant stakeholders involved in OHM development and use. Available information on OHM seed management was first collected from LiveSeeding partners through a workshop. More detailed information regarding quality and diversity management during OHM seed multiplication was gathered from OHM actors via a deep-interview questionnaire.

The primary target audience of this deliverable comprises breeders, farmers, and seed producers interested in developing OHM and/or initiating seed propagation activities.

The deliverable is structured in 4 Chapters: **Chapter 1** presents the definition of OHM, outlines the applicable legal framework governing its production, and introduces digital tools supporting the traceability of OHM production and seed propagation. It also describes the methodological approach applied for collecting information on OHM seed propagation. **Chapter 2** addresses the importance of OHM seed production and quality management, providing background information and key terminology relevant to the topic. This section further presents findings from the LiveSeeding Workshop

and Survey relating to seed production and quality management of OHM. **Chapter 3** focuses on diversity management in OHM. It discusses its relevance and scientific and practical basis in the context of maintenance breeding and seed propagation and concludes with stakeholder experiences related to diversity management during seed multiplication and seed processing. **Chapter 4** provides a practical guideline highlighting specific considerations for OHM seed propagation, covering the full process from planning through pre-harvest and post-harvest stages of seed management. Chapter 5 provides a summary of the main findings and recommendations. This deliverable completes a series of LiveSeeding deliverables on OHM: D2.2 and D2.3, which respectively deal with [OHM notification](#) and the [OHMTrack digital tool](#).

Main conclusions and recommendations

Organic Heterogeneous Material (OHM) offers strong potential to support resilient and diverse agricultural systems. Since 2022, 69 OHM cultivars (46 arable, 23 vegetable) have been notified across nine EU Member States. While genetic and phenotypic diversity distinguish OHM from uniform varieties, both require high-quality seed standards to ensure reliable performance and farm profitability. Thus, the OHM production can build on existing seed systems. Quality of seed can be guaranteed by implementing appropriate measures, taking into account the heterogeneity and dynamic nature of OHM. Key factors to promote OHM include a) a clear understanding of the legal framework and concepts (e.g. maintenance breeding, evolutionary adaptation), b) clear and publicly available information on OHM cultivars and management (seed propagation and maintenance breeding), c) traceability and transparency by open source digital tool OHMTrack, d) targeted training for breeders and seed propagators, and e) further research on diversity management.

Strategies for OHM management and maintenance breeding include evolutionary participatory plant breeding and dynamic management offer interesting perspectives for resilience towards unforeseen biotic or abiotic stresses. Together, these actions can create an enabling environment for scaling up OHM in European agriculture.

Key Conclusions

- **Adoption:** Cultivation is growing but remains limited to small areas. Success depends on better information dissemination and the use of digital tools like OHMTrack.
- **Maintenance & Documentation:** Transparency in breeding objectives and phenotypic traits is essential for traceability. Maintenance breeding must balance consistency with the material's evolutionary potential.

- **Production & Quality:** OHM seed production requires certified organic conditions and standard mechanization. While quality standards (health and purity) mirror uniform varieties, sorting processes must sometimes be relaxed to preserve seed size heterogeneity.
- **Diversity Management:** Maintaining large population sizes (e.g., 10,000 plants for arable CCPs; 100–200 for vegetables) is critical to preventing genetic drift.

Strategic Recommendations:

- **For Policy Makers & Authorities:** Establish a centralized EU list of notified OHM and promote **OHMTrack** as a standardized, open-source notification and tracking tool. Post-marketing controls should be risk-based, efficient, and low-cost to minimize administrative burdens.
- **For Breeders & Propagators:** Provide detailed descriptions of evolutionary potential in notification dossiers. Utilize **participatory breeding** and **dynamic management** (mixing seed lots from different sites) to foster local adaptation and minimize crop failure risks.
- **For Farmers:** Encourage uptake through on-farm trials and practical demonstrations. Farmers should be empowered to share research results via the EU Router Database to build a collective knowledge base.
- **For Consumers:** Shift communication from technical jargon to value-driven narratives. Focus on biodiversity, sustainability, and local adaptation through tastings and digital storytelling.

1. Introduction

Organic Heterogeneous Material (OHM) represents a novel cultivar category characterized by substantial genetic and phenotypic variability and a dynamically evolving population structure, features that may contribute to enhanced resilience to climatic variability. The category was formally introduced by Regulation (EU) 2018/848 on organic production and the labelling of organic products, and its production must comply fully with organic farming requirements. Detailed provisions governing the production and marketing of OHM is established in Commission Delegated Regulation (EU) 2021/1189.

Since the entry into force of the relevant regulatory framework, several notified OHM have become available for cultivation across both arable and vegetable crop sectors, and production activities have been initiated in multiple European countries. Nevertheless, the practical implementation of OHM in crop production systems remains at an early stage. Given that OHM production has only emerged in recent years, seed multiplication activities are likewise recent, and the currently available scientific literature and operational knowledge base remain limited.

The overall objective of this deliverable is to provide consolidated background knowledge and practical guidance on quality and diversity management in OHM seed, drawing on both scientific evidence and stakeholder experience related to OHM development and application. In particular, the deliverable aims to supply operationally relevant information to support seed propagation activities of key target groups, including breeders, farmers, seed multipliers, and competent authorities.

To ensure an evidence-based approach, existing information on OHM seed management was first compiled through a structured knowledge-collection process involving LiveSeeding partners during a dedicated workshop. Building on this initial mapping exercise, more detailed insights into quality and diversity management practices during OHM seed multiplication were subsequently gathered from relevant actors through a targeted survey.

This deliverable completes a series of LiveSeeding deliverables on OHM: D2.2 and D2.3, which respectively deal with [OHM notifications](#) and the [OHMTrack digital tool](#), and the upcoming D1.4 which will update on breeding strategies for OHM and OV ongoing within LiveSeeding.

1.1 About OHM in general

OHM (Organic Heterogeneous Material) is a novel type of cultivar. It is produced under organic farming conditions and is characterized by a high level of genetic and phenotypic diversity within a single plant species, while still sharing some common characteristics.

Unlike traditional varieties, which are bred for uniformity, OHM populations are dynamic in nature, allowing them to adapt to various environmental conditions and resist diseases. This material is produced in accordance with organic regulations and is intended for marketing.

In January 2022, the new EU Organic Regulation (Regulation (EU) 2018/848) came into force. Among other aspects, it regulates the marketing of heterogeneous material produced under organic conditions. Specific requirements for the production and marketing of OHM are detailed in Delegated Regulation (EU) 2021/1189.

OHM is characterized by its **dynamic nature**, which distinguishes it from static, stabilized varieties. Once developed, OHM is managed as a bulk population—repeatedly resown and harvested across successive generations, with the material expected to evolve and adapt to different growing conditions and geographic locations. This inherent capacity for adaptation is not a flaw but a defining advantage of the OHM system.

The Delegated Regulation EU No. 2021/1189 recognizes different primary techniques for developing OHM, each reflecting specific breeding philosophies and starting materials:

- **Composite Cross Populations (CCP)** result from deliberate crosses between diverse parental materials using defined crossing protocols (such as half-diallel, full-diallel, or MAGIC schemes). Following the initial crosses, the progenies are bulked – commonly in the F1 or F2 generation, combining equal or varying quantities of seed from each cross. The resulting population is then repeatedly resown and exposed to natural and/or human selection over subsequent generations, allowing the material to establish genetic equilibrium while maintaining diversity.
- **Dynamic Populations (DP)** are generated through the physical mixing of seeds or plant reproductive material from different sources, such as multiple breeding lines, non-protected cultivars, or accessions from gene banks as well as local and other niche materials. These mixed seed lots are multiplied together as a bulk population for several growing seasons. Recombination occurs naturally

through crossing, in open- but also in self-pollinating crops, leading to gradual trait divergence and adaptation with or without formal selection protocols. (See more information about DP in [Proposal for a toolbox for identification and description of organic heterogeneous material created](#) by LIVESEED project.)

- **Farmers' Selections (FS)** emerge from traditional landraces or other locally adapted populations maintained through on-farm management practices. Farmers may employ mass selection, guided phenotypic choices, or maintenance breeding to preserve and improve these materials over successive generations. This approach connects OHM development to agricultural heritage and local food systems.

Notably, the regulatory framework permits combinations of these techniques and other breeding methods, provided the resulting material maintains sufficient genetic and phenotypic heterogeneity.

Research synthesized within the LiveSeeding framework (for more information on the review of research see section 1.3 of LiveSeeding D2.2) has demonstrated **multiple agronomic, environmental and socio-economic benefits** associated with heterogeneous materials, particularly in organic farming systems. These benefits include:

- **Enhanced disease resilience:** The genetic diversity in OHM creates barrier and dilution effects that reduce pathogen spread and infection efficiency.
- **Climate adaptation and yield stability:** Heterogeneous populations exhibit greater stability of yield and quality traits across diverse growing environments. Some genotypes within the population may tolerate prolonged drought conditions while others may perform better under higher precipitation regimes, collectively reducing the risk of crop loss in variable climatic conditions. This buffering capacity is increasingly valuable as climate change intensifies weather unpredictability.
- **Local adaptation:** OHM populations (depending on the type of OHM and generation) have the potential to evolve toward local environmental conditions when cultivated repeatedly at specific sites. Research demonstrates that populations maintained under organic management over multiple generations develop enhanced traits such as improved root morphology, early vigour, and ground cover – traits particularly valuable for low-input farming systems.
- **Genetic variation:** OHM can serve as dynamic reservoirs of genetic variation, with potential for extracting breeding lines for conventional or organic variety development programs. This complementary relationship strengthens the broader plant breeding ecosystem.

- **Socio-economic resilience:** OHM facilitates decentralized seed production, enables farmer seed-saving practices, and supports regional value chains focused on distinctive agronomic or organoleptic characteristics. The public domain status encourages knowledge sharing and collaborative improvement across the organic farming community.

Organic Heterogeneous Material represents a **new and flexible approach** to plant reproductive material in organic agriculture, emphasizing the importance of genetic diversity and adaptive capacity. Owing to its dynamic nature, OHM supports yield stability, local adaptation, and agroecosystem resilience, while simultaneously promoting decentralized seed systems and active farmer participation. In the context of ongoing climate change, OHM constitutes an important component in the **development of sustainable and resilient agricultural systems**.

1.2 Legal basis of OHM: cultivars and PRM

The current legal framework for **Organic Heterogeneous Material (OHM)** originates from the Commission's temporary experiment on cereal populations 2014/150/EU & 2018/1519 allowing the marketing of cereal populations' seed within Member States. The experiences and the evidence generated during this period (until February 2021), paved the way to extending the concept of population breeding and seed marketing to all crop species, although exclusively under organic conditions (see: LIVESEED booklet #1 [How to implement the organic regulation](#)). Many elements of this temporary experiment have in fact been transposed in the **Regulation (EU) 2018/848** on organic production and labelling. This foundational legislation is supplemented by **Commission Delegated Regulation (EU) 2021/1189**, which provides detailed rules concerning the production and marketing of seeds or more generally plant reproductive material (PRM) of OHM and entered into force on 1st January 2022. In many Member States, National legislation followed suit, outlining the detailed procedures for OHM notification and production.

The basic definition of OHM is contained in Article 3(18) of the Organic Regulation (EU) 2018/848 describing its main characteristics, in particular a **high level of genetic and phenotypic diversity** (see section 1.1).

Under the same article, OHM is also defined as **not being a variety or mixture of varieties** and being **produced under certified organic conditions**.

Article 13 of Regulation (EU) 2018/848 establishes a **notification procedure** that acts as a simplified alternative to the registration and certification systems required for standard varieties. Prior to OHM seed marketing, a supplier must **submit a dossier** to

the competent national authority, in accordance with the provision of (EU) 2021/1189, containing a description of the notified OHM (Art. 4). This description must include: (a) a description of the OHM characteristics; (b) a description of the breeding or production method to obtain the OHM; (c) a description of the parental material and the breeding techniques used; (d) a description of the on-farm management/selection practices; (e) a reference to geographical and pedo-climatic conditions.

A representative sample of the notified OHM must be deposited with the official body to ensure identity and quality at the time of notification.

Once the notification is acknowledged—either expressly or implicitly after three months—the OHM may be listed and its plant reproductive material (PRM) marketed throughout the Union free of charge. In some cases, the relevant authorities may require the applicant to submit additional information.

A comprehensive overview of the implementation of the notification procedure across Member States, is provided in LiveSeeding [D2.2, "Guidelines for OHM notification"](#).

The marketing of PRM of OHM is exempt from the standard certification categories (pre-basic, basic, and certified). However, Delegated Regulation (EU) 2021/1189 mandates specific quality and transparency standards:

- **Seed health and quality** (Art. 6): **OHM PRM must in general fulfil the same standards as PRM of uniform varieties in terms sanitary quality, analytical purity and (with certain exceptions) germination.** In particular, OHM must comply with EU requirements for plant health in accordance with Regulation (EU) 2016/2031 and Commission Implementing Regulation (EU) 2019/2072. Suppliers may derogate from minimum germination rates provided the actual rate is clearly indicated on the label.
- **Labelling** (Art.7): Packages must be identified with the phrase "**Organic heterogeneous material**" and a yellow label featuring a green diagonal cross and be sealed, to prevent tampering. Special provision/derogations for small packages apply.
- **Traceability** (Art. 8): Operators are legally required to maintain records of parental material, production locations, and quantities produced for at least five years to ensure the integrity of the material.

The National Authorities enact **risk-based official controls** to verify compliance with the legislation. Seed health and analytical purity are in the focus of these controls, but they can extend to all aspects of OHM production and marketing.

The notifier remains responsible for **maintenance breeding** of the OHM "where possible" to preserve the main characteristics of the material as described in the original notification dossier. This maintenance must follow accepted practices adapted to heterogeneous material, and the operator must keep detailed records of these activities (see section 3.1 of this deliverable).

Box 1: Variety Mixtures and Dynamic Populations

Article 3(18) of Regulation (EU) 2018/848 establishes that OHM cannot be a mixture of varieties. Under EU seed legislation however, variety mixtures are clearly identified and regulated under several directives, each specific to a crop type (66/402/EEC for cereals, 66/401/EEC for fodder crops, 2002/55/EC for vegetables, 2002/57/EC for oil and fibre crops).

In all these legal texts, variety mixtures are described as mixtures of registered varieties, which must comply with the marketing rules applicable to them before they become components of the blend. These mixtures are re-constituted from the same certified varieties and the same ratios each year. The components and their mixing ratio, must be clearly indicated on the label. Dynamic populations, on the other hand, are type of OHM, obtained by physical mixture of stable breeding lines, gene bank accessions, local varieties/landraces or public domain registered varieties. This dynamic mixture is grown as a bulk for several generations, adapting to specific environmental conditions until it reaches an equilibrium, becoming a dynamic population. Even with self-pollinating crops, such as wheat or peas, with outcrossing rates of 2-5% (or higher under stressful conditions), at each generation new genotypes are generated, co-evolving with the population and increasing its genetic and phenotypic diversity. Therefore, Dynamic Populations should not be associated with static variety mixtures: on the contrary, they constitute valuable class of OHM, often deriving from Participatory Plant Breeding and On-Farm management which can be notified and brought to the market.

1.3 Software tools

The effective management of OHM can be supported by robust digital infrastructure capable of facilitating notification procedures, traceability, phenotypic data collection, and long-term diversity monitoring.

OHMTrack is the digital platform developed within the LiveSeeding project for managing OHM notifications in compliance with EU Regulation 2018/848 and its implementing acts. The system facilitates the formal registration process required for OHM to enter the market. Deliverable [D3.1 "Digital tool for the notification, traceability of OHM seed"](#) describes in detail OHMTrack.

In addition, OHMTrack also is a tool which can ensure the traceability of seed lots of OHM. This function builds the foundation for the quality and diversity management of OHM seeds, which lie at the centre of this deliverable.

The integration of data from phenotypic observations necessitates interoperability with complementary systems specifically designed for this type of data management and diversity analysis.

Phenotypic observations, for characterizing OHM populations (which facilitate e.g. the preparation of the notification dossier) and monitoring the evolution of OHM during the development process, are managed through specialized platforms such as [Seed-Linked](#) and [SHiNeMaS](#). These systems provide structured frameworks for recording field observations, managing experimental trials, and storing phenotypic datasets generated across multiple locations and growing seasons. SHiNeMaS (<https://link.springer.com/article/10.1186/s13007-020-00640-2>) also allows to track seed history across breeding, selection and multiplication steps (Oliveira et al., 2020). In the frame of LiveSeeding task 9.3 on interoperability has already drafted a set of methodologies for phenotypic observations. To standardize data exchange between platforms and other digital tools in the breeding and seed sector, the LiveSeeding project has adopted [BrAPI](#) (Breeding API) protocols. BrAPI provides a standardized RESTful web service specification that enables communication between plant breeding databases, facilitating the aggregation and comparison of phenotypic data regardless of the underlying software infrastructure.

The BrAPI standard defines consistent data models for germplasm, observational units, traits, methods, and scales. Each OHM is registered as a germplasm with observational units representing individual plants or plots within reproduction cycles. The BrAPI observation variable model combines traits (e.g., "plant height"), measurement method, and scale (e.g., "centimeters, continuous"), ensuring semantic clarity and

comparability across operators and locations. The final recommendation for phenotypic observations will be described in detail in Deliverable 9.1 "[Report on internal and external interoperability of LiveSeeding digital tools](#)".

A critical challenge in diversity monitoring is ensuring consistency in trait definition and measurement across different observers, locations, and time periods. To address this, it is necessary the adoption of established ontological frameworks, particularly Planteome and the Plant Trait Ontology (PTO). These ontologies provide standardized vocabularies and hierarchical classifications for plant traits, ensuring that when different researchers or farmers record a specific trait (e.g., awn presence), they are referring to precisely the same biological characteristic measured in comparable ways. The adoption of ontological standards is fundamental for building meaningful datasets capable of supporting longitudinal diversity analysis and enabling cross-population comparisons within the OHM framework.

In this context optional methodologies for monitoring genetic and phenotypic diversity over time in OHM populations can be proposed. This represents a novel challenge as the dynamic nature of OHM, its deliberate heterogeneity and capacity for evolutionary adaptation require monitoring approaches fundamentally different from those applied to uniform varieties.

Unlike conventional varieties that emphasize uniformity, OHM is characterized by inherent phenotypic variability that must be tracked and managed with appropriate strategies across reproduction cycles to prevent genetic erosion while demonstrating regulatory compliance.

1.4 Methodology: Workshop and survey on OHM seed management

Available information on OHM seed management was first compiled through a knowledge-collection process involving LiveSeeding partners during a dedicated workshop. More detailed information regarding quality and diversity management during OHM seed multiplication was subsequently gathered from relevant OHM actors, especially breeders through a targeted in-depth interview.

A **workshop** was held within the framework of the LiveSeeding Annual Meeting on 30th September 2025 in Einbeck, Germany, with the participation of LiveSeeding members. During the workshop, participants were guided through a structured questionnaire (see Annex 2), and their responses were discussed and documented. The workshop explored key dimensions of OHM seed propagation, beginning with a baseline

comparison between OHM and standard varieties, focusing on their biological characteristics, production requirements, and implications for seed systems.

Participants were invited to reflect from the perspective of an OHM seed multiplier, addressing practical entry points into OHM seed propagation, short- and long-term objectives, and relevant knowledge sources, including peer networks, breeders, advisory services, and scientific literature.

Discussions highlighted the main challenges associated with OHM seed production, particularly in relation to seed quality assurance and the management of diversity during seed multiplication and processing. Participants also identified critical steps required to balance genetic diversity with quality standards throughout the production process.

The workshop further collected examples of successful OHM seed production initiatives at both local and international levels, identifying enabling factors such as adapted management practices, collaboration, and supportive institutional contexts. Finally, the session supported follow-up activities by mapping relevant actors, literature sources, and interest in continued engagement through interviews and knowledge exchange.

Part of the collected information was processed after the meeting, and key findings were structured and presented in the following sections of this deliverable (Chapters 2.4 and 3.4). Another part served as the basis for a follow-up survey, helping to define key questions, identify relevant actors in this field, and provide input for the development of guidelines.

The **LiveSeeding survey** was conducted in autumn 2025, targeting OHM breeders and producers to collect information on their seed management practices and challenges. The interview questions are provided in Annex 3. Actors and breeders were contacted that have already officially notified OHM. The actors were contacted for interviews in written or oral form, and the responses cover both arable and vegetable crops and different regions of Europe (see Table 1).

These interview questions focused on practical experiences with OHM seed propagation, covering both technical and management aspects. The interviews explored respondents' roles in OHM seed propagation, the crop species involved, and their practical experience. A major theme was seed quality management, including how quality is monitored, what challenges arise, and which quality parameters are most critical for OHM compared to homogeneous varieties.

Another key focus was diversity management, addressing how OHM is multiplied, maintained, and how cross-pollination and population size are managed to optimize intra-varietal diversity. Finally, the questions examined seed processing and storage, highlighting practical methods, identified challenges, differences from homogeneous seed handling, and ways to avoid unintentional selection during processing. Table 1 shows the list of interviewed OHM actors and their roles in OHM seed management.

Table 1. Participants of the LiveSeeding survey on OHM seed management: involved OHM actors and countries, type of involvement and focus crops

Country	OHM Actor/Organization	Abbreviation of OHM actors	Type of involvement in OHM seed propagation	Crop(s)
DE	Christine Nagel/Bingenheimer Saatgut AG	BSG	Selection and seed production	Spinach
DE	Carl Vollenweider/ Landbauschule Dottenfelderhof e.V.	DFH	Breeding and propagation of breeder's seed	Maize, rye and wheat
DE	Werner Vogt-Kaute	WVK	Breeding and propagation of breeder's seed	Rye, fava bean
DK	Anders Borgen/Land-sorten	LS	Breeding and seed propagation	Wheat and other cereals
EL	Kostas Koutis/Aegilops	AEG	Breeding and selection	Bread and durum wheat, beans, tomato, pepper
FR	Pierre Dorand/Aubepin	AUB	Creation and distribution	Melon, cauliflower, broccoli, zucchini, sunflower
HU	Péter Mikó/HUN-REN, Centre for Agricultural Research	ATK	Breeding and propagation of breeder's seed	Bread wheat and durum wheat
IT	Matteo Pettiti/Reti Semi Rurali	RSR	Participatory plant breeding, maintenance breeding, basic seed production, notification	Bread wheat, durum wheat, barley, einkorn, rice, maize, tomato, sunflower
PL	Artur Paszkowski/Polish Seed Trade Association	PIN	Regulation and monitoring of OHM seed propagation	Maize
PT	Els Wijnstra/ Sementes Vivas	SV	The whole production process till distribution	Fava beans, broccoli, lettuce

Evaluated results of the workshop and survey will be integrated in the next two chapters: Chapter 2 will focus on seed propagation and quality topics and Chapter 3 on diversity management, completed with background information relevant for OHM seed propagation.

2. Seed propagation and quality management

2.1 Seed propagation of OHM

Plant propagation is the process of creating new plants from existing ones and can be categorized into sexual (seed-based) and asexual (vegetative) methods. This deliverable focuses on the sexual propagation of plants; asexual techniques such as cuttings, division, grafting, and layering, which produce genetically identical clones, are outside the scope of this deliverable. This is notwithstanding the fact that crop diversification offers promising perspectives for this category of crop species (see e.g. Finckh et al. 2007).

Seed propagation is a specialized agricultural process involving the multiplication, harvesting, and processing of seeds to maintain analytical and genetic purity, quality, and vigour. It requires careful planning, isolation to prevent cross-pollination, proper cultivation, and rigorous cleaning and control procedures. Well-defined methods exist for the seed propagation of homogeneous varieties; however, with the introduction of OHM, these methods need to be refined to account for their specific characteristics and the objectives associated with producing seeds of this novel cultivar category.

Special characteristics of OHM regarding seed propagation

OHM represents genetically diverse, non-uniform plant populations that adapt to specific environmental conditions, thereby potentially improving disease resistance and yield. Their definition clearly shows that they differ in several characteristics from homogeneous varieties. The main difference compared with uniform varieties is their **heterogeneous nature** manifest at both genetic and phenotypic levels, which is essential for fulfilling the criteria of OHM.

Moreover, OHM is characterized by their **dynamic nature**: they are not mixtures of varieties, nor are they newly created with other methods each year. Rather, an OHM is a population that changes over time as a result of natural or also artificial selection. These specific characteristics have a significant influence on their seed propagation. Seed propagation techniques have traditionally been developed for standard homogeneous varieties, which are not heterogeneous or dynamic or only up to a limited degree¹. **This deliverable therefore aims to describe these specific aspects of OHM in relation to seed propagation and to provide practical recommendations that support their appropriate management and use.** Moreover, according to Organic

¹ For instance, in rye or fodder crops population varieties are in use and play relevant roles.

Regulation (EU) 2018/848, plant reproductive material of **OHM must be propagated under organic field conditions** to meet regulatory requirements.

The three main characteristics—heterogeneity, dynamic nature, and organic origin—are therefore key considerations for their seed propagation from a technical perspective.

Regulatory aspects

The prerequisite for the seed propagation of OHM is notification to national authorities. Notification is a mandatory process for the marketing of OHM, requiring applicants (breeders and/or producers) to submit data in the form of a notification dossier (according to Article 13(2) of Organic Regulation (EU) 2018/848) to the competent national authorities. The notification dossier must contain specific mandatory information about the OHM (see Box 2). Guidance on OHM notification is clearly presented in LiveSeeding [Deliverable 2.2](#)

Box 2: The content of the notification dossier includes

- the contact details of the applicant,
- species and denomination of the OHM,
- description of the OHM:
 - phenotypic characterization (including key common characteristics and heterogeneity)
- Documentation of agronomic and quality traits
- Breeding technique
- Parental material
- Country of breeding, year of production, pedo-climatic conditions
- declaration by the applicant concerning the truth of elements in points a), b) and c)
- a representative sample

Its content, particularly the description of the OHM, provides relevant information for seed propagation: the level of heterogeneity and key common characteristics must be

described in this document, and this description may serve as a basis for guidelines used to verify phenotypic characteristics during seed propagation.

In contrast to OHM, homogeneous varieties must be registered before being marketed. The registration process for homogeneous varieties includes DUS (Distinctness, Uniformity, Stability) and depending on the crop species² also VCU (Value for Cultivation and Use) testing. It is important to note that, since OHM is not varieties (because they are not uniform) within the meaning of Council Regulation (EC) No. 2100/94, they cannot be protected by plant breeders' rights.

In general, seeds of homogeneous varieties appear on the market as certified seeds. According to Article 13 of Organic Regulation (EU) 2018/848, plant reproductive material (PRM) of OHM:

"...may be marketed ... without complying with the certification categories of pre-basic, basic and certified material or with the requirements for other categories set out in Directives 66/401/EEC, 66/402/EEC, 68/193/EEC, 98/56/EC, 2002/53/EC, 2002/54/EC, 2002/55/EC, 2002/56/EC, 2002/57/EC, 2008/72/EC and 2008/90/EC, or acts adopted pursuant to those Directives."

As a simplified alternative to the certification system, Article 9 of Delegated Regulation (EU) 2021/1189 specifies risk-based post-marketing controls for OHM seed implemented by competent authorities. These controls mainly focus on seed quality (germination, analytical purity, and seed health), which are addressed in Chapter 2.2 of this document. Another optional control process during seed propagation may be field inspection, aimed at verifying the traceability and compliance of diverse plant populations rather than the strict genetic uniformity required for certified seeds of homogeneous varieties. Because OHM is characterized by high genetic diversity and dynamic population structure, inspections focus on managing these characteristics within organic farming systems and certification.

The main differences and similarities between seed propagation of OHM and homogeneous varieties from a regulatory perspective are summarized in Table 2.

² No VCU for vegetable and fruit crops

Table 2. Differences and similarities between seed propagation of OHM and homogenous varieties

Factors of interest	OHM	Homogenous varieties
Identity of genetic material	Based on the traceability of its origin (parents, selection process, locations, breeder, etc.), in addition to the description of the OHM in notification dossier	Variety description based on DUS criteria
Complying of seed certification categories (pre-basic, basic, certified)	No	Yes
Relevance of seed quality (Purity, Germination, seed health), more information in Chapter 2.2.	Yes* ISTA methods are applicable	Yes ISTA methods are applicable
Relevance of field inspection to varietal purity and varietal identity	No varietal purity. Risk based controls may be implemented.	Depending on the crop species. If applicable, control of varietal purity and identity based on variety description
Official control	Risk-based	Based on a certification system

* It is a possibility to market PRM of OHM not complying with the minimum germination rates set by legal standard, by indicating the rate of the PRM on the label or the package

Seed propagation methods and steps for OHM

Propagation methods for OHM aim to maintain population diversity and their key characteristics as described in the notification file while ensuring production under organic standards. Seed propagators of OHM must preserve population diversity by using a number of plants large enough to limit random variation in the genetic composition, which can be completed by techniques such as mass selection and negative selection. In addition to deliberate human selection, natural selection can also play a role, allowing the population to evolve over time (see methods in Chapter 3.1 and 3.2).

Furthermore, OHM—and therefore their seeds—must be produced under organic conditions in compliance with applicable legal requirements. Seed propagation of standard varieties is carried out according to a well-established methodology which involves a sequence of scientific and technical procedures designed to maximize seed viability, vigour, and health. The key steps of propagation are divided into two sections: pre-harvest and post-harvest processes, whose definitions and importance are presented in Box 3. Although they are used for standard, homogenous varieties, the

understanding of the relevance and meaning of these processes are very important and useful in OHM seed propagation.

Box 3. Basic processes of seed propagation commonly used for standard varieties

Pre-harvest processes

- **Selection of parent stock:** Selection of the base material from which seed propagation begins. The base material often originates from breeder's seed, and the varietal identity must be guaranteed.
- **Field preparation:** Seed propagation requires optimal field preparation prior to sowing. This includes various agrotechnical operations such as clearing debris, managing weeds, improving soil structure and aeration (via tillage, ploughing, etc.), breaking clods through harrowing, leveling the surface, and maintaining optimal soil moisture.
- **Isolation:** Adequate isolation distance between different cultivars is required to avoid cross-pollination and physical mixing during seed propagation. Cross-pollinated crops (such as maize) therefore require greater isolation distances than self-pollinated crops. Isolation distance ranges are regulated crop-specifically in seed standards and are critical for maintaining the genetic purity of propagated seed.
- **Field inspection:** This is multi-stage process designed to verify the genetic purity, identity, and health of the seed crop. Systematic removal of off-type plants is essential and is usually carried out at the vegetative, flowering, and maturity stages. Field inspection may be conducted by official authorities.
- **Harvesting:** Seeds are collected at physiological maturity. Physical mixing of different cultivars or species may pose a risk at this stage.

Post-harvest processes

- **Drying:** Seed drying is the process of removing moisture from seeds to achieve the required optimal moisture content for long-term storage.
- **Cleaning:** Seed cleaning is the process of removing debris, inert material, and damaged or undesirable (off-type) seeds to improve physical purity and germination rates. Cleaning methods include air-screen cleaning, threshing, and specific-gravity separation.
- **Sorting:** Sorting techniques include mechanical cleaning, density separation using gravity tables, size calibration with sieves, and optical/colour sorting. Proper sorting increases uniformity of vigour, which is a critical factor in high-quality seed production.
- **Treating:** Seed treatments may be applied before sowing to enhance germination, protect against pathogens and pests, and improve seedling vigour. However, apart from physical treatments such as hot water or steam, only a few comply with organic regulations and principles.

The legal framework has allowed the marketing of OHM in Europe since 2022; therefore, the seed propagation of OHM is not yet well documented in either the scientific literature or practical experience.

Within the framework of the LIVESEED project, a Practice Abstract entitled “*How to produce seed of heterogeneous populations of inbred cereals*” (Petitti and Bocci, 2020) was prepared, providing practical recommendations for OHM seed propagators. The authors emphasize the importance of keeping a seed sample from each year, avoiding overly stringent selection practices, and recording crop performance and climate data.

Production and seed propagation of OHM

Notified OHMs have been available for production and marketing in the European Union since 2022. From that date onward, notifications of OHM have been submitted in various Member States across both arable crop categories (wheat, maize, rye, durum wheat, sunflower, fava bean, and field pea) and vegetable categories (common and runner bean, tomato, lettuce, aubergine, pumpkin, zucchini, melon, onion, radish, and spinach beet).

The French authority GEVES publishes a list of notified OHMs, and the complete list at the time of writing is presented in Annex 1. Based on the GEVES database, Table 3. summarizes the currently notified OHMs in Europe, categorized by crop species and country.

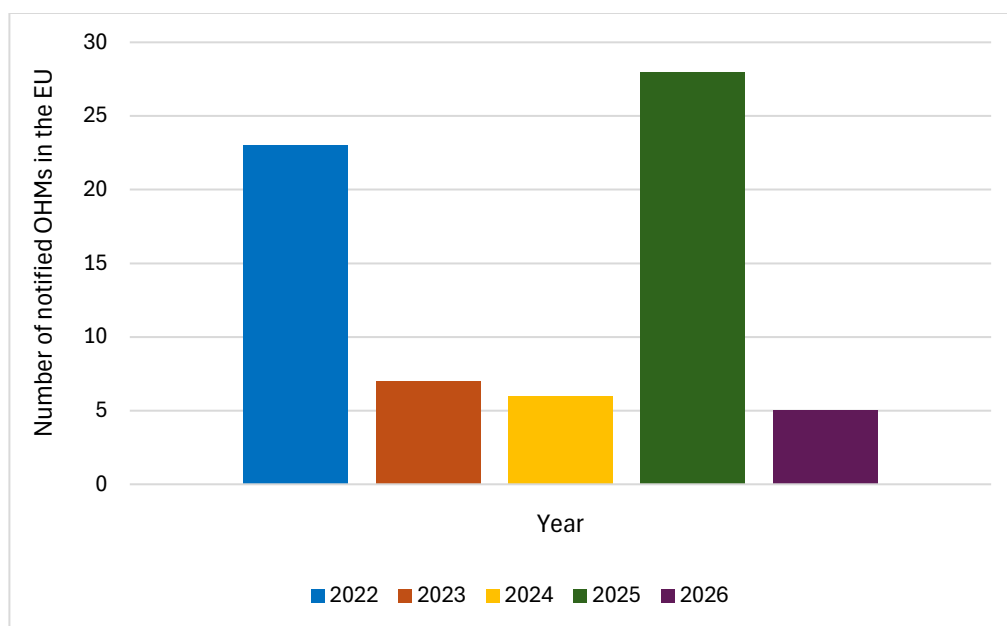
Table 3. Notified OHMs in Europe in March. 2026

Crop species	Notified OHM (no.)	Countries and no. of notified OHM
Maize (<i>Zea mays</i> L.)	14	Germany (8), Poland (4), Czech Republic (1), Austria (1)
Wheat (<i>Triticum aestivum</i> L.)	13	Germany (5), Denmark (2), France (1), Austria (1), Italy (4)
Rye (<i>Secale cereale</i> L.)	4	Germany (3), Austria (1),
Barley (<i>Hordeum sativum</i>)	1	Italy (1)
Durum wheat (<i>Triticum turgidum</i> subsp. <i>durum</i> Desf.)	8	Italy (8)
Fava bean (<i>Vicia faba</i> L.)	3	Portugal (2), Germany (1)

Continuation of Table 3. Notified OHMs in Europe in March. 2026		
Field pea (<i>Pisum sativum</i> L.)	1	Germany (1)
Sunflower (<i>Helianthus annuus</i> L.)	2	France (1), Germany (1)
Common bean (<i>Phaseolus vulgaris</i> L.) and runner bean (<i>Phaseolus coccineus</i> L.)	8	Slovenia (5), Czech Republic (3)
Spinach beet or chard (<i>Beta vulgaris</i> L.)	1	Slovenia (1)
Tomato (<i>Solanum lycopersicum</i> L.)	4	Czech Republic (3), Slovenia (1)
Pepper (<i>Capsicum annuum</i> L.)	1	Czech Republic (1)
Aubergine (<i>Solanum melongena</i> L.)	1	Czech Republic (1)
Lettuce (<i>Lactuca sativa</i> L.)	1	Czech Republic (1)
Zucchini or pumpkin (<i>Cucurbita pepo</i> L.)	2	Italy (1), Czech Republic (1)
Welsh onion (<i>Allium fistulosum</i> L.)	1	Czech Republic (1)
Melon (<i>Cucumis melo</i> L.), watermelon (<i>Citrullus lanatus</i>)	2	Czech Republic (1), France (1)
Radish (<i>Raphanus sativus</i> L.)	2	Austria (1), Poland (1)

In the first year 2022 when this was possible 23 OHMs were notified. Notifications continued in subsequent years, with 7 in 2023, 6 in 2024, 28 in 2025 and 5 in 2026 (Figure 1).

Figure 1. Number of OHMs notified in the European Union by year (2022–March 2026)



In LiveSeeding Deliverable 2.2, data were presented on the cultivation area of OHM in Europe. In the season 2023/24, OHMs were grown on a total area of more than 1,000 hectares (ha) across Europe. The main countries contributing to this total area were Denmark and Germany and the main crops were maize (400 ha), wheat (600 ha), and rye (150 ha). Evidence indicates that OHM cultivation is expanding, especially in countries where new OHM cultivars have been notified.

2.2 Seed quality management

Offering farmers seed of high quality ensures seedlings emerge well and contributes to the development of healthy, stress-tolerant and well-performing crops. Several aspects of a seed batch define its overall quality: physical and varietal seed purity, physiological seed quality and microbiological seed quality.

Physical purity, also called analytical purity, reflects to what extent a seed batch contains only the seeds of the indicated crop species. It is expressed as a percentage. For example, by weight a wheat seed lot might be composed of 99% wheat seed, 0.7% inert matter (such as little stones) and 0.3% seeds of other non-intended crop species or weeds. Analytical purity can be measured in the same way for OHM seed as for homogeneous varieties. Currently, several seed marketing Directives, according to crop species, define the quality standards that must be met in the field for seed production of agricultural plant species and seed lots if the seeds are to be marketed in the EU. These quality standards include the minimum percentage of analytical purity,

and the maximum proportion of seeds of other crop species' or weed seeds in the seed lot. For example, [Council Directive 66/402/EEC](#) regulates the marketing of cereal seed in EU member states. The legal seed quality requirements set for seeds of standard varieties (with certain exceptions for germination capacity, see section 1.1) also apply to OHM seed.

"Varietal" or genetic purity indicates to what extent a seed batch contains seeds of the intended variety, as opposed to seeds with another, non-intended genetic background. In principle, this aspect of seed quality also applies to OHM seed propagation: for example, if seed is marketed as a specific OHM, named "OHM A", users of this seed expect to obtain a seed batch of the indicated heterogeneous population, and not (or only to a very limited amount) seed of a completely different variety or OHM. In seed certification schemes, genetic purity is routinely evaluated at an appropriate development stage (according to plant species) during seed propagation, by counting "off types" in a mainly homogeneous stand of a stable variety. For OHM, ensuring that the seed marketed consists of the indicated OHM and comes with the intended set of traits depends on traceability of seed lots (underpinned by organic certification), appropriate isolation from other crops of the same species and measures to prevent mixing with seed of other (genetic) backgrounds. Checking for visible "off types" in field crops and seeds remain a viable option as well as checking the plausibility of the identity of the OHM. For example, yellow zucchini fruits appearing in an OHM of zucchini supposed to be homogeneous for its green colour trait would be considered a contamination.

Physiological seed quality reflects the germination rate and vigour of a seed batch. Currently, standards for germination rates are set in the Council Directives for seed marketing in the EU, for certified and in some cases (mainly vegetable crops) standard seed. For instance, according to Council Directive 66/402/EEC, wheat, barley and spelt seeds should have minimum germination rate of 85% and maize of 90%. The germination rate of a seed batch may drop e.g. due to poor propagation conditions, untimely harvest or ageing, and seed vigour often also declines. Consequently, germination is slower and more heterogeneous in time, and seedlings are less vigorous and more susceptible to various stress factors. Marketing seed with low germination rate and vigour increases the risk of obtaining a crop with a poor plant density and slow seedling development, making weed and crop health management more challenging. For OHM, a lower germination rate than required by the directives must be clearly indicated on a label (see section 1.2). This ensures consumer trust in OHM and in its production process.

Microbiological seed quality is also often called “seed health”. Understood in a broad sense, it can take into account the entire microbiological communities hosted by seeds, which can have a wide range of beneficial, neutral or pathogenic effects. In its broadest sense, it can even include physiological seed quality and its interactions with the seed microbiological communities. This broad conception of seed health comes with promising perspectives for organic seed, but is not yet fully understood. As seed microbial communities can also be affected by the host plants’ genotype, one may suppose that OHM populations may come with a wider range of different microbial communities. However, to the best of our knowledge this hypothesis has not yet been tested. From a more restrictive and from the legal point of view seed health is usually understood as the absence of seed-transmitted plant pathogens, such as common bean blight (*Xanthomonas* spp.) in common bean or common bunt (*Tilletia* spp.) in wheat. In the EU, some seed-transmitted pathogens, such as the former, are regulated by [Regulation \(EU\) 2016/2031](#), indicating tolerated thresholds and obligatory measures. This regulation and its measures apply to anybody marketing seed in the EU, given the crop species is concerned with one of the regulated plant pathogens. Other seed-transmitted plant pathogens, such as common bunt of wheat, are currently regulated at national level by Member States. Knowing the seed-transmitted pathogens that occur in a given crop species, monitoring for them in the seed crop and seed batches and controlling them is necessary to avoid propagating seed-transmitted pathogens and putting seed users at risk. Several techniques are available to sanitise organic seed affected by a seed-transmitted pathogen, including physical treatments, active substances or certain biologicals. The vast majority can be used for OHM seed in the same way as any other type of variety multiplied under organic conditions (with seed treatments complying with organic regulations). One exception might be density sorting, which has been explored in the LiveSeed project to reduce infection rates with loose smut (*Ustilago nuda*) in barley seed lots. Removing infected seeds based on their lower density might not work in barley populations which are strongly heterogeneous for seed size and density.

2.3 Key challenges

The seed propagation and seed quality assurance of OHM differ to some extent from the methods used for homogeneous varieties. These **differences arise partly from the specific characteristics of OHM—namely their heterogeneity and dynamic nature—which make it essential to take these traits into account throughout the**

seed propagation and quality control process. One of the main challenges is therefore integrating these specific biological properties into seed multiplication practices. **Another important distinction concerns the legal framework governing seed production.** The regulatory requirements for propagating homogeneous varieties differ from those applicable to the propagation of OHM plant reproductive material (PRM). **The legislation is intentionally flexible (in particular, in terms of how the identity of seed lots is guaranteed) in order to support the core principle underlying OHM:** the creation and maintenance of heterogeneous plant material produced under organic conditions and adapted to local environmental factors. **However, for example seed quality must comply with the same requirements established for homogeneous varieties, with the sole possible derogation relating to germination standards.** Although unlike homogeneous varieties OHM seed is not marketed as certified seed, high seed quality shall be ensured for OHM as well. **There are risk-based controls, which focus on seed quality and seed health. These controls should be implemented efficiently in Member States.**

Traceability of OHM is a mandatory requirement under EU Regulation 2021/1189, which helps to secure a high seed quality. The focus is placed on documenting origin, breeding methods, and, where relevant, generation history. **Compliance requires detailed record-keeping for marketing purposes. In this context, the multiplication location and year should also be recorded as part of the transparency requirements and made available to seed customers.**

Specialized digital tools, such as OHMTrack, can support traceability by monitoring seed lot movement and producer information, thereby enhancing transparency and regulatory compliance. **Enabling the interoperability to established system used by seed propagating companies** or possibly also authorities remain an important challenge, which is addressed in the LiveSeeding project.

Maintaining high-quality seed under organic conditions can be challenging, particularly due to seed-borne diseases and weed management issues, which may require targeted and adapted interventions, possibly specific to OHM.

Successful OHM seed production therefore depends on active and continuous collaboration among researchers, breeders, farmers, and regulatory authorities to build credibility and trust in the market. Such fruitful collaborations were established in several countries (e.g. France, Italy, and Germany) within LiveSeeding, and this type of approach should be encouraged to support co-learning on this emerging topic.

The cultivation of OHM is a relatively recent development. Since the regulation entered into force in 2022, in 4 years, nearly 60 OHMs have been notified across Europe,

including both arable and vegetable crops. As both their cultivation and seed propagation represent emerging fields, the most significant constraint at present is the limited availability of practical experience and accessible information.

2.4 Results of LiveSeeding workshop and survey on OHM seed, experience from OHM actors

Several questions in the LiveSeeding workshop addressed the topic of seed propagation and quality management. The corresponding answers and conclusions are presented in this section. In the questionnaire, the term seed production was used as a synonym for seed propagation (see the section 2.1 for a definition).

Results of LiveSeeding Workshop

Workshop participants were asked to share their views on the **specific characteristics of OHM seed propagation**. The responses indicated that, while the technical aspects of OHM seed propagation are not fundamentally different from those of homogenous varieties, several distinctive features exist.

First, the entire process must be conducted under organic field conditions. Traceability was also highlighted as a key characteristic for OHM. Another important aspect is the difficulty of balancing the maintenance of genetic diversity with the need to remove off-types. Participants further emphasized the importance of conducting seed multiplication in appropriate geographic locations, ideally under agro-pedo-climatic conditions similar to those of the original breeding or target environments.

A conceptual tension was also identified as a specific characteristic of OHM seed propagation: OHM must remain stable in identity while inherently being dynamic populations. Avoiding unwanted selection while preserving the evolving nature of the population was considered a fundamental principle when working with OHM (see chapter 3 for more detailed explanations on this point).

Workshop participants were asked to respond to the question: “**How would you start OHM seed production?**”

The responses revealed several key considerations. First, the actor needs to identify a suitable OHM that fits farmers’ objectives and growing conditions. It is also important to identify the relevant market for seed production and/or OHM seed sales. Participants stressed the importance of adopting a value-chain perspective, supported by

appropriate marketing and communication strategies. Finally, awareness of the legal framework governing seed propagation and OHM notification is essential.

Participants were also asked to provide practical guidance for farmers planning to start OHM seed propagation by reflecting on the question: **“What short-term and long-term goals would you set?”**

In the case of OHM, plant breeders sometimes also act as seed producers (i.e. the same person or company), initiating propagation with breeder seed. In any case, it is important to distinguish between seed multipliers and breeders, as their objectives may differ. Breeders may have additional responsibilities such as OHM notification and decisions related to the lifecycle of an OHM. Seed multipliers typically join the process at a later stage.

In the short term, the primary goal is to produce regionally adapted OHM seed with good agronomic performance and high quality, while meeting production requirements.

In the long term, it is essential to maintain key characteristics while allowing adaptation to farm and regional conditions. Sustainable seed propagation also requires the development of stable local markets for OHM seed.

Regarding **seed quality** the workshop participants were asked to contribute to the question: **“What do you consider the most crucial step in ensuring quality in OHM seed production?”**

The contributors highlighted the importance of demand of high seed quality and the producers’s responsibility for good seed quality. It was stated that it is not a risk, if the seed propagator is professional. On the other hand, it is a fact that OHM characterized by a high level of diversity including diversity in seed size, which may lead to confusion between small seed size due to genetic factors and that caused by poor quality leading to lower levels of germination. Seed borne diseases were identified as a possible problem during seed propagation, however, is not a specific problem to OHM, but it could be more pronounced in the case of heterogeneous populations for two reasons. First, seed saving and the concept of OHM are often tightly linked. While seed saving allows for local adaptation, it also involves risks in relation to seed-borne disease. Second, resistance breeding in OHM is complicated by the fact that a single susceptible component or parent, even if is only contained at very low levels, is enough to result in a non-resistant OHM. Barrier or dilution effects which can reduce the pressure with leaf disease in populations do not help with seed-borne diseases.

To ensure high quality OHM seed, the participants recommended to test the seed quality by internal or external laboratories. The testing incurs costs but could increase the value of the seed and the trust in the producer. Traceability of the whole process will also be a guarantee of good quality beyond technical solutions. Crop specific guidelines could also help to propagate high quality OHM seeds.

Results of LiveSeeding survey

Respondents of the survey are mentioned in the answers with the following abbreviations: *BSG* (Bingenheimer Saatgut AG), *DFH* (Landbauschule Dottenfelderhof e.V.), *WVK* (Werner Vogt-Kaute), *LS* (Landsorten), *AEG* (Aegilops), *AUB* (Aubepin), *ATK* (HUN-REN, Centre for Agricultural Research), *RSR* (Rete Semi Rurali), *PIN* (Polish Seed Trade Association), *SV* (Sementes Vivas), more details about respondents can be found in Table 1.

The questions were grouped around the following four topics:

#1 Question: **How do you control seed quality in your OHM seed production?**

Across respondents, seed quality control in OHM seed propagation is described as a **multi-step process combining field monitoring, laboratory testing, and careful seed handling**, largely aligned with conventional certified seed standards. According to *BSG*, *DFH* and *WVK* seed lots are routinely tested for germination capacity and seed health, either in internal diagnostic facilities or in official seed laboratories, using procedures comparable to those applied for certified seed. *WVK* notes that the main difference from certified seed production is the absence of an official field inspection, while laboratory testing remains identical. *PIN* and *SV* explicitly state too that OHM seed quality control follows the same minimum quality requirements as conventional variety seed production, including germination and phytosanitary testing, in line with EU Implementing Directive 2021/1189.

Several respondents emphasise the importance of field-level control, which could be carried out by breeders, seed producers or relevant authorities. *DFH* reports alignment with standard structures through field inspections, seed testing, and a strong focus on controlling common bunt, while *LS* highlights continuous monitoring of production fields for foreign species and wild oat. Similarly, *AEG* stresses the control of seed-borne diseases as a central quality objective.

In addition to testing and inspections, some respondents underline the role of good seed production and handling practices (*ATK* and *AUB*).

Organisational arrangements are also relevant for quality control. *RSR* clarifies that commercial seed production is carried out by organic seed producers within its network, while quality requirements are maintained across partners.

Overall, the responses show a strong consensus that **OHM seed quality control builds on standard seed quality frameworks**, while adapting them to organic and heterogeneous material through emphasis on seed health, adapted field monitoring, and responsible on-farm seed production practices.

#2 Question: Did you identify any problem regarding the OHM seed quality?

Overall, most respondents reported **no major seed quality problems** with OHM (*BSG*, *WVK*, *AEG*, *PIM*), and in some crops such as maize, production was considered comparable to open-pollinated varieties (*PIM*). Where challenges were identified, they were mainly related to **seed-borne diseases—especially common bunt of wheat—which several actors described as the most serious issue under organic conditions** (*DFH*, *LS*, *ATK*, *RSR*). Additional concerns included species and varietal purity, which could be especially important for cereals (*RSR*), loss of small but important genetic components during seed sorting (*RSR*, *DFH*), and the cultural difficulty of accepting morphological heterogeneity (*AUB*), while in specific national contexts, strict phytosanitary rules (e.g. zero tolerance for bean weevil in fava beans in Portugal) were highlighted as a significant barrier to OHM seed circulation (*SV*).

#3 Question: What are the most important processes to ensure high-quality OHM seed?

Across respondents, ensuring high-quality OHM seed is described less as a single technical step and more as a **chain of careful, well-coordinated processes spanning field management, harvest, processing, and testing**. Several actors emphasized that, in principle, the existing seed production practices already work well for OHM (*BSG*, *SV*). Core elements repeatedly mentioned include field control and inspection, cleaning and sorting, and attention to germination quality (*DFH*, *WVK*, *RSR*).

Respondents stressed the **importance of field-level management** during seed multiplication, including official and multiplier field inspections, hand weeding, to remove off-types and impurities, and advisory support to farmers to avoid impurity of seed (*DFH*, *WVK*). These steps are seen as especially crucial for maintaining species purity in heterogeneous materials. **Post-harvest processes** such as seed cleaning, colour sorting, and careful sorting technology were highlighted as essential tools to maintain quality without unintentionally losing valuable diversity components (*LS*, *RSR*).

Crop-specific handling was also emphasized, proper drying of seed is important in many crops, such as maize to ensure high germination (*DFH*). *AEG* also referred to seed health management measures, such as hot water treatment or vinegar use, as practical tools to reduce seed-borne diseases.

Beyond technical operations, selection and genetic decision-making were described as an integral part of quality assurance in OHM, involving long-term observation, data collection, and informed choices—alongside an acknowledgment that a certain degree of unpredictability (“luck”) is inherent in biological systems (*AUB*). *ATK* highlighted the importance of starting from **high-quality basic material**.

Finally, *PIN* pointed out that certification and plant health requirements, particularly for quarantine pests and diseases, represent a major bottleneck rather than on-farm practices themselves. While maize was not considered problematic, certain species require costly laboratory tests and specialized equipment, which can be prohibitive for small-scale seed producers.

#4 Question: **Which parameters do you find more important in the case of OHM compared to homogeneous varieties? Why? (Germination, physical purity, moisture content, seed health)**

Across respondents, there was broad consensus that **the key quality parameters for OHM—germination, physical purity, moisture content, and seed health—are largely the same as for homogeneous varieties**. Several actors explicitly stated that they do not see meaningful differences at the parameter level between OHM and homogeneous material (*BSG*, *WVK*, *AEG*, *SV*). From this perspective, the same quality standards should apply, and all parameters are considered equally important when aiming for high-quality seed (*RSR*).

Where differences were mentioned, they were **crop-specific rather than inherent to OHM as such**. In maize, seed size was not considered problematic due to its open-pollinated nature, while seed-borne diseases—particularly *Fusarium*—were identified as a slightly greater challenge in OHM compared to homogeneous varieties; other parameters, such as physical purity, were seen as comparable (*DFH*). Similarly, in the Polish context, OHM making all quality parameters generally achievable at a level similar to homogeneous material; however, **differences in maturation within populations** can complicate the choice of harvest date and thereby influence final seed quality (*PIN*).

Several respondents emphasized **seed health as the most critical parameter**, particularly because of bunts in wheat under organic conditions (*DFH*). From this perspective, physical purity—especially weed contamination—is also closely linked to propagation site selection, and concerns were raised that OHM seed production may sometimes be placed on less favourable fields if farmers prioritise their best land for commercial varieties (*ATK*).

Beyond standard parameters, one respondent pointed to **additional qualities that become more relevant in OHM**, such as the possibility of farmer-led selection and the importance of genetic diversity. The capacity of OHM to adapt to changing conditions through free reproduction and on-farm selection—ideally in dialogue with breeders—was seen as a distinctive strength, while conventional quality criteria themselves were not considered problematic (*AUB*). Finally, one perspective noted that **pure lines may actually pose greater challenges**, implicitly suggesting that heterogeneity in OHM does not necessarily translate into lower seed quality and may even ease certain constraints (*LS*).

Key learnings are based on the results of the workshop and the survey and are presented in Box 4.

Box 4. Key learnings about OHM seed propagation and quality management

- **OHM seed propagation is technically comparable to conventional systems**, but requires adaptation to organic conditions and the management of genetically diverse populations.
- **A fundamental challenge is balancing diversity and stability**, as OHM must maintain identity while allowing ongoing adaptation and evolution.
- **Long-term sustainability depends on local adaptation and stable markets**, highlighting the need to combine agronomic performance with economic viability.
- **Seed quality management largely follows existing standards**, with similar parameters (germination, purity, moisture, seed health) and testing methods as conventional seed systems.
- **Trust in OHM seed quality is strongly linked to professionalism and transparency**, including traceability and, where possible, laboratory testing.
- **Field-level practices are critical for ensuring quality**, particularly monitoring, selection (removal of off-types), and disease management during seed multiplication.
- **Seed-borne diseases represent the main technical risk**, especially under organic conditions, while most actors report no major overall quality issues.
- **Traceability and organic production conditions are essential**, serving as key guarantees of quality and trust beyond purely technical measures.

3. OHM maintenance breeding and diversity management

3.1 OHM breeding and maintenance breeding

In this section first a brief overview on OHM breeding, i.e. the development of new OHM cultivars, is provided. Building on that some basic aspects of maintenance breeding of OHM are outlined.

Breeding of OHM:

The existing legal framework – the Organic Regulation and Delegated Regulation (EU) 2021/1189 – offers a range of different options for the development of OHM cultivars. In order to utilize the full potential of OHM, it is important that breeders and other stakeholders are aware of these possibilities.

OHM can be developed for both predominantly self-pollinating as well as outcrossing crop species. The mating system determines many aspects of OHM breeding. An excellent review for both crop types is given by Dawson & Goldringer (2012).

Considering the wide range of options, it is essential that clear breeding objectives are set, ideally in collaboration with stakeholders along the value chain. Breeding strategies should be planned accordingly. Examples of concrete breeding objectives include specific (product) quality traits, resilience to (a)biotic stress factors, local adaptation or the conservation of genetic resources.

The development of OHM can be integrated in existing breeding programs or evolutionary participatory breeding (EPB; Murphy et al. 2005) approaches led by farmers can be pursued. Innovative combinations of these approaches have been proposed (e.g. Simon-Kutscher & Kussmann 2025).

EPB or strategies of “dynamic management of crop diversity” (see section 3.2a) place the focus on the development of locally adapted cultivars. Accordingly, the conditions at the (multiple) target sites determine the planning of the breeding process. Key questions regarding the significance of the nature of the environmental influence – in particular whether it is directed over several selection cycles (e.g. a prolonged drought) or undirected/heterogeneous – are discussed e.g. by Bocci et al. (2020) or Dawson & Goldringer (2012).

The development of OHM involves the following basic steps (adapted after Döring et al. (2011)):

- (re)combination of genetic diversity (e.g. by hand crossings of the parental plants),
- multiplication and bulking of the initially created components,
- selection phase, and
- use of the developed OHM as germplasm for the next breeding cycle.

The first two steps imply several key decisions that breeders have to take (Döring et al. 2011). The first decision is about the breeding method or the type of OHM, i.e. whether it is a Composite Cross, Dynamic or Farmers' Selection Population (CCP, DP or FS; see section 1.1). Moreover, breeders have to specify the

- number and identity of parental genotypes (taking breeding objectives into account),
- crossing scheme and contribution of the different components, and finally
- the number of OHM candidates that can be created (depending on available resources).

The steps of initial creation are followed by the selection phase: EPB approaches emphasise that natural selection improves the individual fitness of plants and contributes to site-specific adaptation. It should be noted that harvesting and seed cleaning equipment always affect the composition of OHM, and these can be supplemented by more targeted methods such as sieve or gravity sorting or colour separation of seeds (see sections 2.1 - 2.4). Moreover, under the existing legal framework, directed selection by breeders is explicitly allowed. Negative mass selection entails e.g. the removal of diseased or the tallest plants (counteracting adverse evolutionary forces at the population level; Denison 2012). Positive mass selection can be used to improve various traits, including quality traits, although care must be taken to avoid a too drastic restriction of genetic diversity (see section 3.2a). More elaborate schemes including ear-to-row, analytical or yield progeny testing or the recurrent creation and re-integration of lines can be implemented to ensure an accelerated breeding progress (Dawson & Goldringer 2012, Murphy et al. 2005).

Finally, it should be stressed that it is essential *when* in the development process of OHM certain selection methods or other measures are applied, e.g. in self-pollinating crops if selection is practiced during segregating (<F6) or in later generations. Clear breeding schedules, including when the seed is distributed to farmers or multipliers, should be outlined together with the involved partners.

Maintenance breeding of OHM:

Recital no. (11) of the Delegated Regulation (EU) 2021/1189 states that the objective of maintenance breeding of OHM is "to ensure identity and quality [of the material], if such maintenance is possible". The concrete legal basis is then presented in Article 10 of the regulation:

"Where maintenance is possible, the operator who has notified the OHM [...] shall preserve the main characteristics of the material at the time of its notification, by maintaining it as long as it remains on the market. That maintenance shall be undertaken according to accepted practices adapted to the maintenance of such heterogeneous material. The operator responsible for the maintenance shall keep records of duration and content of maintenance.

At all times, the competent authorities shall have access to all records [...]. The operator shall keep those records for 5 years after the moment the [...] OHM is not marketed anymore."

To gain a better understanding of this legal basis, two basic facts of OHM should be recalled:

- After their initial creation, OHM are managed as so-called bulk populations in subsequent generations. The OHM are subject to natural and optionally also directed selection, and the harvested seed is mixed (=bulked) before each growing cycle.
- Evolutionary plant breeding (EPB) relies on the fact that agronomically relevant parameters are improved by natural selection. This tends to be the case for grain crops since the fitness of individuals (defined as the number of grains per plant) is positively correlated with grain yield (Jain 1961)³.

The dynamic nature of OHM will necessarily lead to genetic and phenotypic changes over time. As a consequence of the two facts stated above, the magnitude of these changes cannot be (fully) controlled by breeders. This is consistent with the requirement of the Delegated Regulation that the maintenance breeding of OHM has only to be carried out "if possible" or the extent that it is possible.

Notwithstanding, OHM will always be managed – in accordance with the Delegated Regulation – by an operator in specific locations using well-defined seed multiplication and selection methods. Moreover, the notification dossier includes as an integral part a description of the OHM specifying key common phenotypic characteristics, the heterogeneity as well as agronomic and quality traits of the material. An important additional requirement is that the traceability of seed lots is guaranteed.

By definition, a seed lot belongs to an OHM if

- it shows the characteristics as described in the notification dossier and if
- it is correctly tracked.

³ For other (root or leaf) crops OHM can still be developed, however, the improvement of the cultivars have to be managed by directed selection.

In that sense the objective of maintenance breeding of OHM can be understood as to keep the characteristics of the OHM consistent with the description in the notification dossier and to ensure the traceability of seed lots.

The prerequisite for this is that the OHM has to be carefully described. In particular, the dynamic nature and evolutionary potential of the material has to be taken into account. Among other factors, this evolutionary potential for genetic and phenotypic change depends on the type of the OHM, level of heterogeneity, its mating system and generation.

Directed selection methods by breeders can be applied to keep the material within the description of the notification dossier. Selection in maintenance breeding could be a continuation of the routine in the development phase (e.g. in terms of the targeted traits and methods). However, often the intensity of the selection will be lower and/or the focus will be placed on maintenance rather than the improvement of traits. Potentials for (yield) improvement within the permitted boundaries of the OHM description can be still realised, which is, in fact, an advantage of OHM over standard varieties.

Maintenance breeding will be often applied to a source, "elite" or "mother" population by the breeder/notifier of the OHM. Selection methods can be practiced more intensively on that population and special care can be taken e.g. with regard to isolation (in particular in outcrossing crops). Implementations within the framework of dynamic management systems offer interesting perspectives, as described in the next section.

3.2 OHM diversity management (dynamic management)

Principles and strategies for OHM diversity management

As a consequence of Article 3(18) of Regulation 2018/848, OHM must be characterized by a **high level of genetic and phenotypic diversity** between individual reproductive units, such that the plant grouping is represented by the material as a whole, rather than by a small number of constituent units. This involves the use of specific management practices for maintenance breeding to preserve inherent genetic diversity; a process that can be referred to as dynamic management. Dynamic management of crop diversity has been proposed in 1984 as a strategy to enhance within-species variability complementary to *ex situ* conservation (Goldringer et al 2001). However, it is still relevant to consider its principles within the context of OHM maintenance breeding. According to Enjalbert et al. (2011), dynamic management "*aims at conserving a reservoir of genetic variability rather than specific alleles at a locus or some cultivars that are*

already genetically fixed. Its principle is to maintain the context in which evolutionary forces can act on genetically diverse cultivated populations so that they adapt to changing climatic conditions, emerging diseases and agricultural practices." Dynamic management of genetic diversity only really makes sense within a metapopulation context, i.e. several distinct populations connected by gene flows and which might go extinct or recolonized through dispersion (Levins 1969, Hanski & Gilpin 1991), a level of organisation which is predicted and was shown to be stable and maintain diversity on a long-term range.

Therefore, to optimize dynamic management of OHM diversity within each case of maintenance breeding, the four evolutionary forces (natural and human selection, genetic drift, mutation and migration) should be considered. While **genetic drift and mutation** will only depend on the demographic sizes of the populations, **natural and human selection** can be modulated by the choice of the environments where the populations are propagated, the choice of agronomic and selection practices. Finally, **migration** occurs in two ways: pollen flows among populations which depends on the mating system and distance among fields and should be avoided, and mixing of seeds harvested from different populations, which is a powerful method to mitigate too drastic differentiation of populations and the risk of genetic diversity loss.

Although **mutations** introduce new diversity at an extremely low rate at each locus in the genome, when considered across the entire genome and across all plants in a field, this can represent a non-negligible contribution. In most cases, as the aim of maintenance is to preserve the OHM's original characteristics, it may be necessary to eliminate outliers through negative mass selection. However, it will be much more difficult to detect those outliers than in conventional DUS varieties.

Genetic drift causes random variations in allele frequencies within a population through the sampling of a finite number of individuals and seeds to form the next generation. The greater the number of plants from which seeds are harvested and the number of seeds sown, the more limited the variations in frequency and the genetic drift will be. This mechanism is modulated by the reproductive system of the species in question (self-pollination will reduce (by a factor of 2 at most) the diversity contributed by each seed). The risks of genetic diversity loss can be illustrated in concrete terms by the concept of effective population size (N_e), which represents the size of an idealized population that would experience the same magnitude of random fluctuations in allele frequencies due to genetic drift only as the population under study. It is recommended that the effective population size be greater than 1,000 individuals in order to maintain genetic diversity and reproductive capacity in the long term

(Frankham et al 2014). Brumlop et al (2019) adopted a more rigorous approach and estimated the demographic size (i.e. the actual number of plants grown and harvested) required for CCP wheat populations to achieve an N_e of 5,000. This figure ranged from 12,000 to 17,000 plants which is typical for arable crops. However, this is under the hypothesis that there is no selection in the OHM population. Enjalbert et al (2011) and Knapp et al (2020) estimated the effective population size actually observed in similar wheat CCP populations after 10 generations of reproduction by using genetic markers to measure variations in allele frequencies and found N_e values ranging from 50 to 300 with demographic sizes between 10,000 and 32,000. The difference between both numbers (effective and demographic sizes) is due to the additional effect of **selection**, which also induces variation in the genetic composition. Yet, although the low estimated genetic effective size indicates strong natural selection occurring in these populations, no significant loss of genetic diversity was detected at the time scale of 10 generations.

To conclude, for arable crops, in the case of OHM obtained from highly diverse CCPs, growing 10,000 plants is far enough to avoid strong genetic diversity loss even with natural selection occurring, over a time scale consistent with maintenance breeding. For vegetable crops where a lower number of plants has to be handled, the demographic size can be lowered to 100-200 plants. However, to maintain N_e as large as possible, exactly the same number of seeds per plant should be sampled to constitute the next generation, thereby setting the variance in reproductive success among plants close to zero.

Natural selection is both an asset and a challenge. On the one hand, it leads to the OHM adapting to local conditions, and even to specific practices, as well as to any changes these may undergo over time. On the other hand, the plants that have an advantage within a heterogeneous population may be the most competitive (e.g. increased frequency of the tallest plants in Enjalbert et al. 2011; Knapp et al 2020;), which is not necessarily a desirable trait for the OHM. Agronomic practices should be carefully chosen to both reinforce interesting natural selection effects (e.g. growing the OHM population under low nitrogen conditions to ensure it remains suited to this environment) and avoid selecting for competitive advantage over other plants of the same species. **Human selection** may complete natural selection by discarding clear off-types and unadapted plants (e.g. with diseases) (negative selection) or by retaining plants with the best behaviour (positive selection). The final number of selected plants should meet the requirements set out above.

Migration through pollen flows from other fields should be avoided by isolating the OHM with distances depending on the species (similar to conventional varieties isolation). **Migration** through mixing seed lots coming from different sub-populations of the same OHM is the best way to maintain genetic diversity at the global (meta-population) level (Enjalbert et al 2011). Environments and agronomic practices chosen as maintenance breeding sites should all correspond the targeted conditions described for the OHM in the notification file. Then mixing seeds lots of x small sub-populations of n plants will reduce the effects of genetic drift compared to a single large one of xn plants as variation in frequency in each population is random. Growing the OHM population at different sites by different farmers or breeders is also a way to minimize risks of losing the seeds due to a cultivation failure and to distribute the work among several actors.

Using genomic approach to monitor OMH diversity evolution during maintenance breeding

The management of OHM represents a significant shift from the traditional focus on variety uniformity toward a strategy of resilience through diversity. This diversity allows the material to adapt to changing environments, making it a critical tool for organic agriculture and climate change mitigation. Because OHM is inherently dynamic, maintaining its quality and competitiveness requires traceability of seed lots and an adapted seed quality management (as described in Chapter 2). Monitoring phenotypic characters and in particular the genetic composition of OHM over time represents interesting areas of research.

While phenotypic approaches rely on visual assessments of traits and complete documentation, genomic monitoring provides a higher-resolution, and more objectivity in understanding a population's status. Phenotypic assessments are often delayed by environmental "noise" and may only reveal the loss of diversity after it has reached a critical point. In contrast, molecular genomic techniques can detect subtle shifts in allele frequencies that indicate how a population is responding to local selection pressures or whether it is suffering from genetic drift. By identifying the underlying genetic structure, breeders can ensure that the "adaptive breadth" of the population is preserved.

Managing Diversity from Breeder to Farmer

Over several generations of multiplication, the population is likely to adapt to the farming practices and to the agro-pedoclimatic conditions of the local site. While this

local adaptation is often beneficial, it can also lead to the loss of certain alleles that might be necessary for resilience in future, different years. Therefore, it can be potentially useful for breeders to provide a baseline genetic description upon sale, and for multipliers to periodically monitor the population to track its evolutionary trajectory.

Technical Implementation: Pooled Genotyping and Haplotypes

Monitoring the hundreds of individual plants required to accurately represent a population is often prohibitively expensive. To overcome this, the recommended approach is pooled-population genotyping combined with haplotype-based data processing. Using whole-genome re-sequencing (WGS) at ultra-low coverage, such as 0.03x per genotype, allows for cost-effective data collection. To achieve high precision at such low depths, the frequencies of closely located polymorphisms are aggregated into small haplotype blocks. This up-sampling strategy capitalizes on the biological background of the crop and has been shown to increase the precision of allele frequency estimates by magnitudes compared to simple single-marker analysis. Special care must be taken when selecting the genotyping approach. Modern genotyping arrays and sequencing strategies often include a multiplication (amplification) step to increase DNA uniformity. This step introduces biases, negatively affecting precision.

Linking Genomic Data to Actionable Traits

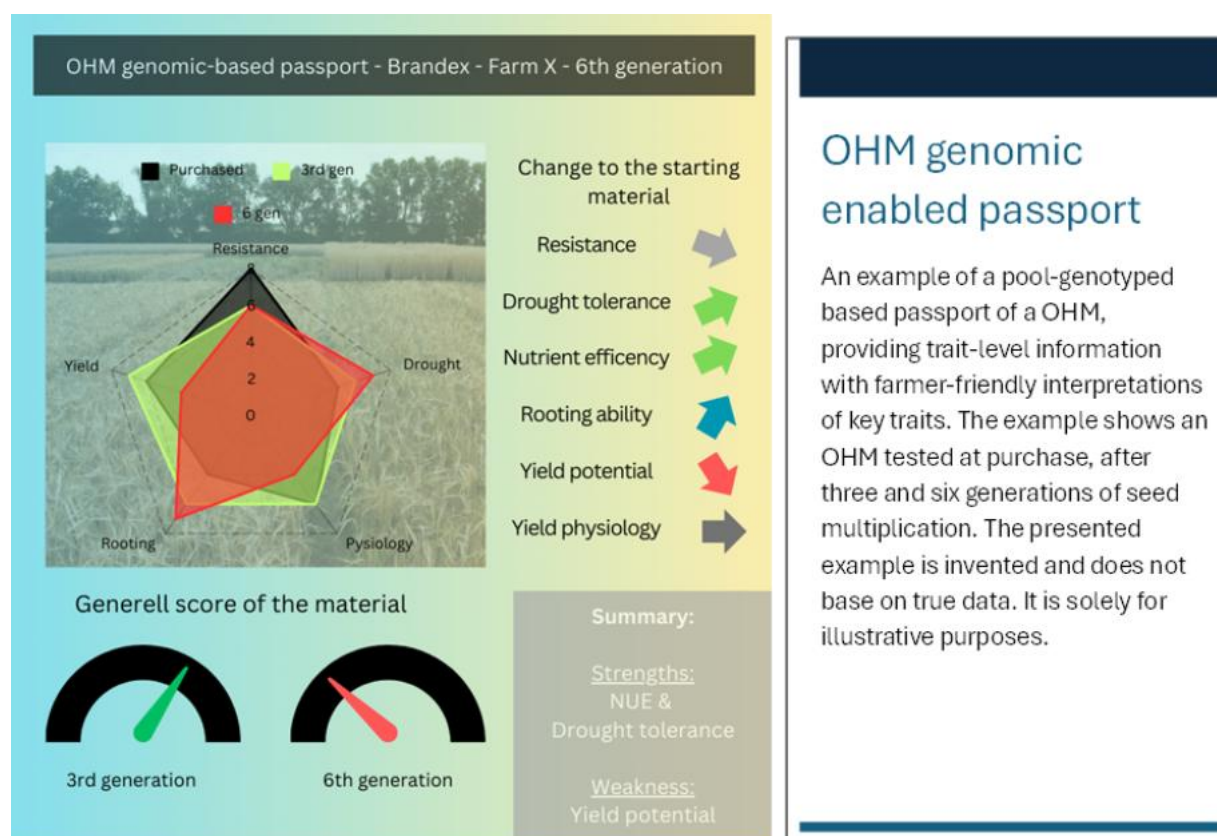
Although the genetic information collected may indicate whether an OHM has changed across generations after notification or purchase, a major goal is to translate genetic data into meaningful physiological information. By linking allele frequency changes to specific traits such as fungal resistance, drought tolerance, or nutrient use efficiency (NUE), breeders and farmers can assess an OHM's health status and resistance. For example, if a population originally contained a high frequency of fungal resistance alleles that subsequently dropped due to a series of dry years with low infection pressure, the population may become vulnerable to future outbreaks. In such cases, genomic data serves as an early warning system, allowing the breeder to intervene by selecting in a high-pressure environment to replenish the necessary resistance genes.

Best Practices and Recommendations

To maintain the initial attributes of the OHM and map it using genomic approaches, it is recommended to use a pooled genotyping approach with a minimum sample size

of 300 individuals. Higher values are recommended when rare alleles are to be detected. When creating populations, using more than two parental lines is encouraged to maximize initial diversity, though this requires more advanced sequencing strategies to track each parent's contribution. If parental information is available, short-read sequencing is often sufficient to relate SNPs to a reference haplotype. For more complex natural populations where parents are unknown, long-read sequencing technologies, combined with computational haplotype restoration from population genotyping data, are necessary to achieve the resolution required for meaningful assumptions. Regular genomic "audits" every few generations during maintenance breeding can potentially help to ensure that the OHM remains a robust and productive resource for (organic) farming across various microclimates and environments.

Figure 2. OHM genomic passport – Changes in the performance of an OHM over six generations



3.3 Results of LiveSeeding workshop and survey on OHM seed management, experience from OHM actors

Different aspects of diversity management in OHM propagation were explored with LiveSeeding partners and OHM actors through the workshop and survey.

Results of LiveSeeding Workshop

During the LiveSeeding Workshop, participants were invited to reflect on challenges and practical considerations related to managing diversity in the propagation of OHM. Their inputs provide insight into both operational constraints and enabling factors across the seed multiplication and processing phases.

The discussion focused on the following guiding questions:

#1 Question: **“What are the main challenges of working with heterogeneous materials in terms of managing diversity during seed multiplication and seed processing?”**

- **Diversity management during seed multiplication**

Participants consistently highlighted that effective diversity management begins with a clear understanding of the breeding objective of the OHM. Maintaining alignment with the original purpose of the material—such as ensuring resilience through genetic variability—was considered essential throughout the multiplication process.

A key operational requirement identified was the need to monitor and validate genetic and phenotypic diversity under field conditions. Participants noted that this process is facilitated by the official OHM description developed during the notification stage, which provides a reference framework for maintaining material integrity.

Several enabling factors for successful diversity management were identified, including:

- availability of suitable production fields
- practical experience of seed producers
- adequate technical skills and staffing capacity
- effective coordination of field operations

Regular field inspections were also considered critical to maintaining population integrity during multiplication by some participants.

- **Diversity management during seed processing**

Participants emphasized that diversity management during seed processing presents distinct technical challenges. Access to appropriate equipment was identified as a key prerequisite for ensuring effective handling of heterogeneous seed lots.

The primary risk at this stage relates to unintended selection during seed cleaning and grading, particularly due to variability in seed size within OHM populations. Participants stressed the need to balance seed quality requirements with the objective of preserving genetic diversity.

Several operational considerations influencing the success of OHM propagation were identified:

- determining the optimal harvest timing for heterogeneous materials
- defining minimum seed lot sizes required to prevent genetic drift
- establishing recommended multiplication cycles for maintaining population stability

These considerations indicate that seed propagation should be guided by breeder recommendations, while acknowledging that evolutionary changes in OHM populations may occur over time and are consistent with the adaptive nature of such materials.

Participants also highlighted challenges and opportunities related to variability in stress tolerance and disease resistance within heterogeneous populations, noting that environmental pressures may inadvertently drive selective shifts in population composition.

#2 Question: “What do you consider the most crucial step in ensuring diversity in OHM seed production?”

A central finding was the importance of ensuring that seed propagators have a clear understanding of the breeding objectives and intended characteristics of the OHM. This is guaranteed if the breeder and seed propagator are the same operator, but this will not be feasible in all cases.

From a technical perspective, several priority practices were identified:

- ensuring sufficient cross-pollination within OHM populations
- preventing genetic contamination from external sources
- implementing careful seed cleaning procedures adapted to heterogeneous seed characteristics

Participants also emphasized the importance of adopting flexible maintenance approaches that allow both preservation of the original material and context-specific adaptive selection.

Finally, it was noted that sustainable OHM breeding and maintenance require viable organizational and business models, such as those implemented in existing systems (e.g. the Danish Landsorten model).

Results of the LiveSeeding Survey

Respondents of the survey are mentioned in the answers with the following abbreviations: *BSG* (Bingenheimer Saatgut AG), *DFH* (Landbauschule Dottenfelderhof e.V.), *WVK* (Werner Vogt-Kaute), *LS* (Landsorten), *AEG* (Aegilops), *AUB* (Aubepin), *ATK* (HUN-REN, Centre for Agricultural Research), *RSR* (Rete Semi Rurali), *PIN* (Polish Seed Trade Association), *SV* (Sementes Vivas), more details about respondents are shown in Chapter 1.4. (page 17).

The survey aimed to address specific questions related to diversity management of OHM during seed multiplication, maintenance, processing, and storage.

Diversity management during seed multiplication and maintenance

#1 Question: **How do you maintain your OHM? Do you have a recommendation or protocol?**

Across respondents, approaches to maintaining OHM range from **highly structured population management** to more **open, evolutionary and practice-based strategies**, reflecting both different breeding philosophies and different stages of implementation. Several organizations noted that they are not yet in a formal maintenance phase, either because selection has not started or because the OHM are still very new (*BSG*, *SV*). In these cases, maintenance protocols are seen as a future task rather than an established practice.

Where maintenance is already taking place, many respondents emphasized that OHM are generally **maintained as population**. Genetic change is accepted as part of the process, while consciously observing changes over time and occasionally repeating the same crosses to compare generations (*WVK*). This approach treats evolution as inevitable but manageable.

More detailed **population-based strategies** were described for cereals. *DFH* explained that OHM is often set up as dynamic populations initially derived from breeding lines, with a clearly defined source, basis or mother population maintained by breeders and then shared with farmers. While on-farm selection is possible, keeping the core population under breeder responsibility was seen as important for safeguarding overall genetic diversity. The need to balance local adaptation against maintaining

the full genetic spectrum was highlighted, along with the recommendation to follow standardized protocols, even when working with dynamic materials (*DFH*).

Other respondents described **minimal or targeted intervention** approaches. In some cases, maintenance focuses mainly on avoiding impurities and seed-borne diseases, without actively steering natural selection processes (*LS*). **Evolutionary population management** was described as a continuous cycle of seed saving, replanting, and observing, where each year a representative seed sample is replanted, allowing the population to evolve while monitoring key traits such as yield, disease resistance, and plant height (*AEQ*).

A more explicitly evolutionary perspective emphasized that OHM shall be actively allowed to evolve, guided only by a small set of essential selection criteria that may themselves partly change over time in response to context and emerging needs (*AUB*). Finally, *RSR* highlighted the importance of **basic seed maintenance plots**, suggesting that a minimum, carefully monitored area (e.g. at least 1,000 m²) should always be maintained as a reference from which seed production can be restarted. *ATK* described a more informal approach, in which OHM is reproduced as infrequently as possible—taking germination capacity into account—with the aim of preserving their original characteristics.

#2 Question: **In your opinion, what is the most critical step at OHM seed multiplication and maintenance?**

Respondents largely agreed that the most critical step in OHM seed multiplication and maintenance lies in **balancing genetic integrity and diversity with practical quality control**, while avoiding contamination and loss of traceability. *BSG* stressed that it is essential to clearly describe the material and ensure that OHM quality remains consistent and reliable for growers, even though they are inherently dynamic.

A recurring concern was the **risk of contamination**, particularly during harvest. The use of external harvester was seen as a major risk factor for introducing foreign seeds from the same or other species. This challenge was described as crop-dependent, being less problematic in species such as fava beans, which are easier to separate (*WVK*). Field size was identified as a critical factor, with smaller plots making it more difficult to avoid impurities (*LS*).

From a breeding and population-management perspective, **maintaining sufficient genetic diversity** was highlighted as a central challenge. This includes decisions about the number of plants needed to maintain a population, while recognising that improvement-oriented selection may require smaller, more focused populations. *DFH* emphasized that the core challenge is to maintain the population in an efficient an

intentional way, aligned with its purpose. Related to this was the need to safeguard genetic integrity while preventing contamination (*AEG*).

ATK pointed to **field-level agronomic practices** as decisive for successful multiplication, including weed control, careful soil preparation before sowing, and applying targeted treatments against fungi and pests such as cereal leaf beetle. These measures were seen as critical for maintaining both seed quality and manageability under organic conditions.

RSR stressed that these technical challenges cannot be addressed without **strong capacity building**, highlighting the importance of educating farmers and seed producers about the specific risks and responsibilities associated with OHM.

Beyond technical and agronomic issues, **traceability and regulation** emerged as key critical points. Because OHM is dynamic and evolving, ensuring traceability once the material has been sold to farmers was described as particularly challenging (*PIM*). In a similar vein, legal uncertainty was highlighted as a major constraint: Possible questions are whether OHM should be maintained exactly as initially notified, or whether continued selection and adaptation are permitted within the regulatory framework (*SV*, see sections 3.1).

Finally, one respondent framed the critical step more holistically, emphasizing that OHM maintenance ultimately depends on informed genetic choices, systematic observation, data collection, and collaboration with other breeders and farmers, while also accepting a degree of uncertainty inherent in working with living, evolving materials (*AUB*).

#3 Question: **How do you manage cross-pollination in heterogeneous populations, if relevant?**

Across respondents, **cross-pollination in heterogeneous populations is generally managed in the same way as in homogeneous varieties, the question is much more crop specific**. Several actors stated that they follow standard isolation distances and conventional seed-production rules, emphasizing that OHM does not fundamentally change the logic of pollination management (*BSG, LS, RSR, AEG, DFH*). For some organizations, the question was considered not relevant, either because of the species they work with or their production context (*ATK, PIN, SV*).

Where cross-pollination was identified as relevant, respondents highlighted crop-specific risks and practical constraints. In strongly cross-pollinated species such as maize and rye, **field isolation is considered essential** (*DFH*). In contrast, for self-pollinated species such as wheat, cross-pollination was generally viewed as less important, and physical mixing during harvest or processing was considered a greater risk than pollen

flow (*DFH*). Some organizations work exclusively with cross- or partially cross-pollinated species and therefore to manage cross-pollination an inherent part of their breeding and multiplication system (*WVK*).

AEG framed cross-pollination not only as a risk but also as a potential benefit if it occurs within the OHM, particularly in self-pollinating species, where occasional cross-pollination was seen as contributing to evolution, adaptation, and resilience within heterogeneous populations.

#4 Question: **How many plants/replications are needed for population integrity?**
Respondents broadly agreed that **an appropriate population size depends strongly on the species, breeding system, OHM type and the underlying level of genetic diversity.**

BSG referred to minimum thresholds around 100 plants as a baseline for maintaining populations in case of spinach, especially in small-scale or early-stage maintenance. Others described working with a few hundred plants as sufficient and practically feasible in cereals (*LS*). More conservative approaches emphasized larger population sizes for cereals, with at least 1,000 (*AEG*) or 8,000–10,000 plants (*ATK*), as a way to robustly preserve diversity plants recommended for cereals to maintain population integrity over time.

Crop-specific strategies were frequently mentioned. According to established practices, at *DFH*, in case of maize, around 500 cobs are harvested/OHM and year, followed by sorting and selecting the best 100 for continued multiplication (sown within a larger population of some of the rest of the material), while in wheat, the recommended population size is based on the suggestion of Brumlop et al. (2019) to maintain an effective population size of 5,000 plants (without taking into account the effect of selection, see section 3.2a).

Some respondents highlighted that population size should be considered in relation to breeding objectives. One strategy acknowledged the inevitability of genetic change and addressed it by periodically introducing new crosses, with improved populations replacing older ones when performance justified the change (*WVK*). Another emphasized that required plant numbers depend on the number of parental lines and overall genetic diversity, recommending cereal seed distributions of at least 1 kg as a starting base, and minimum populations of around 400 plants for crops such as tomato, maize, and sunflower (*RSR*).

SV stressed that thresholds are still being explored, particularly in less-studied species. For fava beans, large multiplications of more than 1,000 plants were maintained

without a defined lower limit, while for broccoli, minimum population sizes of around 150–200 plants were under consideration.

#5 Question: How do you maintain intra-varietal diversity over generations?

Responses indicate that maintaining intra-varietal diversity in OHM is understood less as a fixed conservation task and more as a **managed evolutionary process**, with different actors positioning themselves at various points along a spectrum from deliberate maintenance to intentional evolution. *BSG* noted that they are not yet at a stage where formal strategies are fully defined but anticipate the need to at least describe and monitor the range of traits expressed within a population as a first step. *WVK* expressed uncertainty and even a perceived pressure to reduce diversity.

A more process-oriented perspective highlighted that population size is central to maintaining diversity, as too few plants can accelerate the loss of components through competition and drift. *DFH* noted that over time, certain components may dominate and suppress others, leading to a gradual reduction in diversity. Occasional outcrossing, although low in rate, can also accumulate across generations. From this viewpoint, the main recommendation is to avoid major management errors, such as selecting too few plants or over-cleaning seed lots, as farmers' practices can unintentionally erode diversity.

LS stated that they do not intensely manage intra-varietal diversity but also allow natural selection to shape populations over time. *AEG* described a more structured yet still evolutionary strategy, in which initial varieties are maintained separately, but populations are allowed to diverge across locations and years, leading to context-specific expressions of the same starting material.

AUB reframed the question, arguing that their goal is not to maintain internal diversity in a static sense, but to allow OHM to evolve. From this perspective, diversity is dynamic and time-dependent, and seed harvested in different years may represent distinct "versions" of the same population.

Spatial strategies were also highlighted as important tools for sustaining diversity. Producing OHM in multiple locations and either maintaining these populations separately or mixing seed samples across sites was seen as a way to buffer against local selection pressures and maintain broader genetic variation (*ATK*, *SV*). At the same time, it was acknowledged that some loss of diversity is both expected and acceptable, particularly under strong selective environments such as hot or dry climates (*RSR*).

#6 Question: How do you prevent unintentional genetic change or narrowing?

Across respondents, **unintentional genetic change or narrowing is widely recognized as an inherent risk in OHM**, but one that can be mitigated through population management, spatial strategies, and careful selection practices, rather than fully eliminated. *BSG* emphasized that they apply the same basic precautions used for homogeneous varieties, such as maintaining sufficient isolation distances to avoid unintended pollen flow, particularly in cross-pollinated crops.

A recurring theme was the importance of population size and representativeness. Drift was most often associated with selecting too few plants, which can rapidly narrow genetic diversity. Respondents highlighted that maintaining large and representative populations, including all desirable types at each seed multiplication cycle, is essential to counter this risk (*DFH, AEG*). In maize and rye, specific risks such as inbreeding depression due to self-pollination were noted (*DFH*).

Several respondents described adaptive management approaches that explicitly accept change as inevitable over time. In these cases, genetic narrowing is addressed not by trying to freeze populations, but by periodically developing new populations or replacing older ones when diversity or performance declines (*WVK*). Others focused on avoiding contamination—from other fields or seed lots—as the primary way to prevent unintended genetic change (*LS*).

More systematic strategies combined field observation, repeated evaluation across seasons, and data-supported selection decisions to prevent excessive genetic change driven by narrow or unintended criteria. In these approaches, isolation of growing areas was paired with structured monitoring of traits to ensure that selection remains aligned with broader population goals (*AUB*).

Spatial diversification and temporal buffering were also highlighted as effective safeguards. Producing OHM in multiple locations and mixing seed samples across sites was seen as a way to counteract local selection pressures and maintain broader genetic variation (*ATK*). In addition, respondents emphasized the importance of keeping seed from previous generations as a backup, enabling producers to revert if natural selection bottlenecks or unintended narrowing occur (*RSR, SV*).

Diversity management during seed processing and storage

#1 Question: Which methods do you use for drying, cleaning, and sorting OHM seed?

Across respondents, there was strong agreement that OHM seeds are generally dried, cleaned, and sorted using the **same equipment and methods as used for seed processing of homogeneous varieties**, and that no fundamentally new technologies are

required. Several actors explicitly stated that they rely on standard seed company infrastructure and existing facilities (*BSG, AUB*). Others confirmed that cleaning procedures follow those used for certified seed production (e.g. *WVK, LS, SV* and other respondents).

Where differences were highlighted, they related mainly to **the intensity of cleaning and sorting rather than the methods themselves**. Several respondents emphasized that, particularly for dynamic populations, over-cleaning and strict sorting should be avoided, as these practices can unintentionally remove valuable genetic components. Standard machines such as wind cleaners and sieves were widely used, primarily to remove weed seeds, but with a deliberate decision to apply less strict sorting than would be used for homogeneous varieties (*DFH*). This cautious approach was seen as especially important in populations with a limited number of components, while larger composite cross populations were considered less vulnerable to diversity loss through cleaning.

Several respondents noted that seed sorting by size is generally avoided in OHM, except to remove clearly damaged, very small, or non-viable seeds. Sorting was instead focused on species purity and basic seed health, rather than achieving uniform seed size (*AEG*). In some cases, alternative techniques such as densitometric cleaning with air were used instead of traditional sieving, particularly to remove weed seeds while minimizing selection pressure on seed size (*ATK*).

Drying practices were described as largely crop- and climate-dependent. For maize, natural wind drying was commonly used for small quantities in Germany, while wheat often required little or no drying at all (*DFH*). In Mediterranean contexts, *RSR* noted that drying is rarely a limiting factor for cereals, with established drying facilities available for crops such as rice where needed. Similarly, maize OHM were described as straightforward to handle because they are open-pollinated materials rather than hybrids and therefore do not require additional post-harvest processing steps (*PIM*).

#2 Question: **Did you identify any problems regarding OHM seed processing and storage?**

Across respondents, there was strong consensus that **no major problems have been identified in relation to OHM seed processing and storage**, and that these steps are largely comparable to those used for homogeneous varieties. Most actors explicitly stated that they had not encountered specific difficulties, or that OHM seeds do not pose additional challenges compared to standard seed lots (*BSG, WVK, DFH, LS, AEG, AUB, PIN, SV*).

Where potential limitations were mentioned, they were framed as practical or scale-related rather than OHM-specific. One respondent noted that certain seed processing technologies—such as special cleaning systems—have lower throughput, making them well suited for small lots but less efficient for larger-scale production. However, this was not seen as a constraint for storage, where no differences from conventional seed were identified (*ATK*).

Another respondent highlighted a potential risk linked to seed sorting equipment, particularly systems that unintentionally select smaller or lighter seeds. This was described as population-specific, as some OHMs display sufficient uniformity in grain size to avoid this issue, while others may be more sensitive to size-based selection during processing (*RSR*).

Storage conditions and practices were consistently described as fully comparable to those used for seeds of homogeneous varieties.

#3 Question: **What differences did you find between the seed processing of OHM and homogeneous material?**

Overall, respondents reported few fundamental differences between the seed processing of OHM and that of homogeneous varieties, with most stating that the same processing steps and infrastructures are used. Several actors explicitly noted that they had not observed any differences at all, or that OHM seed can be processed in essentially the same way as used for homogeneous varieties (*WVK, LS, ATK, PIN, SV*).

Where differences were identified, they were primarily linked to **greater variability in seed traits**, rather than to the processing workflow itself. Several respondents highlighted variation in seed size, weight, and colour as the most noticeable distinction, which can interact with seed cleaning and sorting equipment and occasionally create practical challenges (*BSG, RSR*). In this context, differences were most often encountered during sorting (*AEG*).

One respondent underlined that while the physical processing steps may not differ, information management becomes more critical for OHM. This includes rigorous labelling, careful storage, and maintaining access to detailed records for each harvest year—such as field observations, measurements, and statistical results—to ensure traceability and transparency over time (*AUB*).

#4 Question: **How can selection bias be avoided during processing?**

Responses indicate that selection bias during processing is a recognised but context-dependent issue, and that its relevance varies strongly by crop, processing technology, and the structure of the OHM population. *WVK* suggested that selection bias cannot

always be fully avoided, as minimum quality requirements—such as seed size needed for reliable sowing—inevitably impose some level of selection during processing. To avoid selection bias there is no seed calibration for spinach OHM at *BSG*, but this makes it difficult for technical seeding.

Respondents emphasised that too strict sieving and size calibration can unintentionally remove important components of heterogeneous populations, and therefore recommended moderate, purpose-oriented processing intensity (*DFH*, *ATK*).

AEG framed the issue in terms of selection logic, recommending the use of negative selection only—that is, removing clearly damaged, diseased, or unwanted seeds—rather than positively selecting for uniform size or appearance. This approach aims to preserve as much internal diversity as possible while still ensuring basic seed quality. Additional avoiding measures were also mentioned. *RSR* described recovering part of the discarded seed fraction and reprocessing it with different machine settings, allowing potentially valuable components to be reintegrated rather than permanently excluded due to a single processing pass.

Several respondents noted that selection bias is not considered a significant issue in certain crops or contexts. In cereals, it was described as it could be irrelevant (*LS*), while in maize OHM, the level of diversity was seen as sufficiently robust that no special measures were required, at least over the first few production cycles. However, it was acknowledged that bias could become more relevant over longer time horizons or in materials that are closer to simple mixtures rather than genuine OHM (*PIM*). Others reported that the issue was not relevant in their specific case (*SV*, *AUB*).

Key learnings are based on the results of the workshop and the survey and are presented in Box 4.

Box 4. Key learnings about diversity management during seed multiplication and processing of OHM

- **Diversity management is central to OHM seed propagation**, requiring continuous alignment with the original breeding objectives while allowing adaptive evolution under field conditions.
- **Effective diversity management depends on both technical and organisational capacities**, including suitable fields, skilled staff, coordinated operations, and regular field inspections.

- **Maintaining diversity requires balancing preservation and adaptation**, combining safeguarding of core population traits with context-specific, on-farm selection processes (see section 3.1).
- **Population size is a critical determinant of diversity preservation**, but optimal thresholds are species-specific and still partly experimental, especially for less-studied crops (see section 3.2a).
- **Seed processing introduces a key risk of unintended selection**, particularly during cleaning and sorting, where variability in seed size can lead to loss of valuable genetic components.
- **Contamination (especially during harvest and handling) is a major operational risk**, requiring careful management of machinery, field size, and isolation practices.
- **Seed processing and storage largely rely on standard technologies**, with no fundamental differences from standard varieties, but requiring adjusted intensity to avoid over-selection.
- **Avoiding selection bias requires moderate, purpose-oriented processing**, focusing on removing clearly unfit seeds rather than selecting for uniformity.
- **Information management and traceability are particularly important**, as dynamic populations require detailed records across generations to ensure transparency and continuity.
- **Capacity building and knowledge transfer are essential**, as successful diversity management depends on informed decision-making by breeders and seed producers.

4. Practical Guidelines for OHM actors (breeders, seed propagators)

A practical guideline was developed based on the results of the LiveSeeding Workshop and Survey, focusing on OHM seed propagation. The guideline outlines the basic steps of the entire process, from activity planning through technical implementation, and highlights the work processes that require special attention due to the unique characteristics of OHM.

Planning

Definition of aims

At the initial stage, it is crucial to define the purpose of OHM propagation, as this may vary: it could be on-farm multiplication (by breeder or farmer) or contractual seed

production. What is the intended production volume and crop species? Which priority is more important: preserving the original characteristics of the OHM, or allowing for its dynamic evolution (as in evolutionary populations)? After clarifying these questions, the planning of seed propagation area is a crucial step.

The size of the propagation area must be aligned with these objectives and with the amount of seed expected. If the goal is the conservation or regeneration of the base material (core or mother population), this is best carried out on a smaller area and is usually the responsibility of the breeder or should be done in close cooperation with them. In contrast, when multiplication is intended to supply seed for further cultivation, a larger seed propagation area is required, ideally proportional to seed demand. Smaller plots are easier to manage but may present a higher risk of physical admixture and genetic drift, whereas seed propagated on larger areas generally allows better maintenance of genetic identity and reduces the likelihood of unintended mixing due to scale and spatial buffering.

Information Gathering

Seed propagators must be familiar with the regulatory framework governing the cultivation and seed propagation of OHM, as well as with the general objectives of OHM cultivation, in order to work successfully. In addition, they should understand the overall process, aims, and technical solutions of seed propagation in general; knowledge and practical experience in this field are essential for effective implementation.

Specialised training materials on OHM are available through the LiveSeeding project (see links to [training materials](#) and [webinars](#)). General information on OHM regulation is also accessible. An excellent introduction to the legal basis of OHM is provided in a booklet and an accompanying short video prepared by the non-governmental organisation Artemisia AISBL (Brussels) in collaboration with the online exchange platform Seeds4All:

https://liberatediversity.org/wp-content/uploads/2022/02/OHM_Booklet_S4A.pdf

<https://www.youtube.com/watch?v=BDkomih6oWY>

Technical Requirements

The agricultural machinery necessary for the technical implementation of propagation (such as soil cultivation equipment, a seed drill, and a combine harvester) must be available; these may be owned or rented. Seed processing requires specialised equipment, including cleaning and packaging machinery. In general, the propagation of OHM does not require specialised technical infrastructure compared to seed propagation of homogenous varieties.

Ensuring the traceability of OHM requires proper batch documentation, for which dedicated software is available, such as OHM Track, specifically developed for this purpose.

Multiplication site

Careful selection of the seed propagation site is essential. The most important prerequisite is that the OHM must be propagated under organic conditions. Based on general experience, it is advisable to multiply an OHM in an area with agroecological characteristics similar to those of its original production environment, especially if the goal is to preserve its original traits. Propagation under different environmental conditions may lead to changes in the OHM population during multiplication; this is also permissible, provided it is consistent with the intended objectives.

Pre-harvest processes

Field Conditions

As a general rule, field conditions for seed propagation should be as optimal as possible, taking into account the specific requirements of each crop species. Efforts should be made to prepare an optimal seedbed to ensure uniform emergence and strong early development. It is also important to adhere to the optimal sowing time for the given crop species.

Considering the flowering biology of the cultivated OHM (whether open-pollinated or cross-pollinated), an appropriate isolation distance may be maintained from other cultivation areas of the same species. Isolation distances are not OHM-specific; therefore, the standard isolation distances generally applied to uniform varieties could be followed as a guideline.

Monitoring and Field Inspections

Based on the available OHM description, monitoring and validating genetic and phenotypic diversity during seed propagation is essential. Field inspections carried out by the breeder are highly valuable in this process. Regular field inspections are critical for maintaining population integrity during multiplication. Inspections may be official (conducted by authorities) or performed by the breeder or the seed producer and better all together. At this stage, it is important that the inspector is familiar with the specific OHM. Knowledge of its characteristics is necessary to maintain population integrity, remove off-types, and avoid significant (or unnecessary) genetic drift.

Careful weed management and plant protection practices in the field can help ensure the production of healthy seed, but these must comply with organic farming regulations. Continuous monitoring of production fields for foreign species and wild oat, and their removal, is an effective way to achieve high physical purity of the seed after harvest. These techniques are not specific for OHM, but very helpful to get clean seed in case of heterogeneous populations where the post-harvest cleaning methods are limited due to heterogeneity of seed.

Harvest of OHM Seed

This is a critical stage and must be carried out at full physical maturity. In the case of OHM, any differences in maturation time resulting from population heterogeneity must be taken into account. In practice, the risk of physical admixture with other species or genotypes is highest during harvest; therefore, thorough cleaning of the harvester before starting this operation is an essential step.

Post-harvest processes

Quality Management

The quality requirements for OHM seed (physical purity, germination, and seed health) are aligned with conventional seed standards. An exception is permitted only for germination; in such cases, the actual germination rate must be indicated on the seed label or packaging. Overall, seed testing is essential for producing high-quality OHM seed. Quality testing of OHM seeds does not require special equipment or techniques; standard methods (based on ISTA rules) commonly used in conventional seed testing are applicable.

Seed quality is closely linked to field production and processing practices. Physical purity can be improved through careful field monitoring and the removal of foreign species and harmful weeds. Harvesting at the optimal time is one of the most effective ways to ensure high germination rates.

Particular attention must be paid to seed health (e.g. common bunt in cereals). If bunt infection is detected—potentially already in the field—the seed must be tested before any processing.

Practices against common bunt in cereals were presented in several Liveseed Practice Abstracts (PA): No 2. [“Managing common bunt in wheat seed lots”](#), PA No. 41. [“Application of acetic acid as a seed treatment in organic cereal seed”](#) and in PA No. 59. [“Treating wheat seed with vinegar against common bunt”](#).

Seed Processing

Firstly, it is important to note that the technologies and infrastructure used for seed processing are the same as those applied for homogeneous varieties, and the processing steps are largely similar.

Seed drying is primarily dependent on crop species and climatic conditions rather than being OHM-specific. The goal is to reach the appropriate moisture level for further processing and storage. No special drying methods are required for OHM; conventional techniques are fully applicable.

Seed cleaning and sorting require particular attention in the case of OHM in order to preserve the original heterogeneity of these materials, cleaning and sorting are identified as critical stages in OHM seed propagation. Excessively strict cleaning should be avoided, as it may reduce population heterogeneity. The cleaning process should therefore be limited to removing impurities (such as weed seeds and contaminants) and damaged, very small, or infected seeds. Continuous monitoring of the result of cleaning is recommended to check the physical purity and diversity of OHM (if it is possible) and to find a manageable compromise. Uniform seed size is not required for OHM, so seed calibration is generally avoided.

Storage of OHM seed does not require special solutions; standard seed storage requirements are sufficient.

5. Conclusions and recommendations

The cultivation of organic heterogeneous material (OHM) has become possible in Europe only in recent years, following the entry into force of the relevant legal framework in 2022. Since then, a substantial number of OHM have been notified, and a wide range of OHM cultivars is now available in both arable and vegetable crops.

Seed production forms the foundation of crop production and of the agricultural sector as a whole, as it fundamentally determines yield quantity, product quality, and overall farm profitability. High-quality seed — characterized by genetic integrity, high germination capacity and vigour, high physical purity and seed health — is a primary prerequisite for competitive crop production.

This principle applies equally to OHM as to homogenous plant varieties. However, in the case of OHM, specific characteristics must be taken into account throughout the production process, notably their genetic and phenotypic diversity and their dynamic population structure.

#1 Conclusion – increased uptake of OHM across EU Member States

It can be concluded that a total of 69 OHM have been notified in 9 European countries (Austria, the Czech Republic, Denmark, France, Germany, Italy, Poland, Portugal, and Slovenia). A wide range of OHM is currently available in both arable and vegetable categories; however, their cultivation is still limited to relatively small areas. Based on plant classification, 12 species and 23 OHMs belong to vegetable crops, while 8 species and 46 OHMs are arable crops. Uptake could be increased through broader dissemination of information on available materials.

#1 Recommendation for breeders, authorities, and policy makers

Provide more extensive and accessible information on cultivable (notified) OHM at both EU and national levels (e.g. via the EU Router Database or equivalent platforms). The EU Commission should compile a list of all notified OHM and promote the open source digital tool OHMTrack for notification and tracing of OHM with the aim to enable OHM in all EU Member States. For consumers: OHMs' communications should be based on simple, value-driven messages that highlight biodiversity, local adaptation, and sustainable food production. Instead of technical terms, clear labeling, brief explanations, and product stories should be used to demonstrate why these products

offer added value. Promotion should be supported by tastings, appearances at farmers' markets, and digital campaigns so that consumers come to recognize OHMs as a positive, high-quality, and forward-looking choice.

For farmers: The adoption of OHMs should be encouraged through practical demonstrations, demonstration farms, and locally-based on-farm trials so that producers can see their benefits in their own circumstances. It is important that farmers have easy access to seeds, cultivation information, and technical support, as this reduces the risk of trying out new practices. Adoption can be further strengthened by programs and market collaborations that demonstrate OHMs offer real opportunities not only from an agronomic perspective but also from economic and marketing standpoints. It would also be beneficial to provide farmers with information on how to use the [EU Router Database](#), including the terms of access and the option to upload on-farm research results in PDF format. This would facilitate the sharing of practical experiences and improve access to knowledge related to OHMs.

#2 Conclusion – documentation of performance of OHM

Maintenance breeding of OHM can be understood as the process of keeping the specific characteristics of the material consistent with the description in the notification dossier and to ensure the traceability of seed lots.

#2.1 Recommendation for breeders and seed propagators

The prerequisite for maintenance breeding of OHM is its careful description in the notification dossier, which should take into account the evolutionary potential of the material. Among other factors, this evolutionary potential for genetic and phenotypic change depends on the type of the OHM, level of heterogeneity, its mating system, and generation.

The description of the OHM covers not only phenotypic traits and agronomic characteristics but also the breeding objective and the expected degree of heterogeneity within the population. Making this documentation of notified OHM publicly accessible by national authorities could facilitate the use and maintenance of the OHM.

Directed negative or positive (mass) selection by breeders can be applied to keep the material within the description of the notification dossier. Concrete available methods are described in section 3.1.

The multiplication locations and years may be recorded as part of the transparency requirements and made available to seed customers.

To implement the traceability of seed lots, the digital tool OHMTrack should be promoted and widely used to ensure effective traceability at all stages of OHM production and multiplication. This tool is also useful for tracking the quantities of seed sold for each OHM, as required by the regulation.

#2.2 Recommendations for policymakers

It is recommended that national authorities use the OHMTrack tool as a standardized, open-source solution for receiving and processing OHM notifications and supporting their tracking, as this simplifies administration and makes the process more transparent. In Member States where a proprietary digital system is already in place, it is advisable to ensure its full compatibility with OHMTrack and common EU data standards so that data can be linked at the EU level. During implementation, it is particularly important that the system be accessible via a web interface and an API, as this reduces the burden of duplicate data entry and facilitates data exchange between authorities and market participants.

#3 Conclusion – OHM seed production

OHM seed production must be conducted under certified organic conditions. Besides strict separation from conventional seed production, it does not require specialized infrastructure. However, the same level of mechanization used in homogenous variety seed production can ensure appropriate seed quality. One exception might be the avoidance of strict seed sorting in case of heterogeneity in seed size of a given OHM. Seed testing methodologies and quality requirements, especially with respect to Plant Health Regulation remain equivalent to uniform varieties.

#3 Recommendation for seed propagators

Comprehensive knowledge of standard seed production practices is essential for successful OHM seed multiplication. Adequate mechanization capacity is also required.

#4 Conclusion – PRM quality control of OHM

Plant reproductive material of OHM need to fulfil the same standards as PRM of uniform varieties in terms sanitary quality, analytical purity and (with certain exceptions) germination. Appropriate quality of OHM seed and maintenance of OHM cultivars can be guaranteed and monitored by risk-based controls.

#4 Recommendation 4 (for breeders, seed propagators, and authorities)

The risk-based post marketing controls must be carried out efficiently and proportionate by official authorities, with costs aligned with the principles of the legal framework for OHM — namely no notification fee and a low-cost approach with limited administrative burden.

#5 Conclusion – diversity management of OHM

Different concepts and strategies for the management of heterogeneity in OHM, which can be implemented in seed propagation and maintenance breeding, have been proposed. The population size must be large enough to reduce genetic drift.

#5 Recommendation for breeders, researchers, and policymakers

The required population size for OHM maintenance and seed propagation depends in particular on the OHM type, degree of its heterogeneity and mating system.

For arable crops, in the case of OHM obtained from highly diverse CCPs, growing 10,000 plants is enough to avoid strong genetic diversity loss even with natural selection occurring, over a time scale consistent with maintenance breeding. For vegetable crops where a lower number of plants has to be handled, the demographic size can be lowered to 100-200 plants. However, to maintain an effective population size (N_e) as large as possible, as equal numbers of seeds per plant as possible should be sampled to constitute the next generation.

Strategies of “evolutionary participatory plant breeding” and “dynamic management of crop diversity” (see sections 3.1 and 3.2) enable the development of locally adapted cultivars. The conditions at the (multiple) target sites determine the planning of the breeding process. Evolutionary adaptation of the OHM is expected in such crops.

In dynamic management, migration through mixing seed lots coming from different sub-populations of the same OHM is used to maintain genetic diversity at the global (metapopulation) level. Growing the OHM population at different sites by different farmers or breeders is also a way to minimize risks of losing the seeds due to a cultivation failure and to distribute the work among several actors.

Targeted training programmes could support OHM operators and seed propagators in better understanding both the importance and the practical approaches to diversity management. Genotyping tools represent an interesting approach for evaluating heterogeneity, particularly in the context of OHM research and breeding.

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Annex 1: List of notified OHM

List of notified Organic Heterogeneous Materials in EUROPE published by French authority GEVES (<https://www.geves.fr/variety-seed-expertise/organic-agriculture/organic-heterogeneous-material/>)

	Species	Member State	Denomination	Operator	Date of registration
1	<i>Allium fistulosum</i>	Czech Republic	Variace zimnich sek	Marek Kvapil	15/07/24
2	<i>Beta vulgaris</i> L. – Spinach beet or Chard	Slovenia	Tanja	Ekološka kmetija Ipavec , Mitja Ipavec	30/11/22
3	<i>Capsicum annuum</i>	Czech Republic	Měňavka	Marek Kvapil	3/03/22
4	<i>Citrullus lanatus</i>	Czech Republic	Dračí vejce	Marek Kvapil	15/01/26
5	<i>Cucumis melo</i>	France	Patoutafaifix	L'Aubépin	7/12/25
6	<i>Cucurbita pepo</i>	Czech Republic	Lofthouseova zimní tykev	Marek Kvapil	7/02/23
7	<i>Cucurbita pepo</i>	Italy	Zucchini Novus	Arcoiris s.r.l.	12/08/25
8	<i>Helianthus annuus</i>	France	Milpa Altus	Milpa Semences	7/12/25
9	<i>Helianthus annuus</i>	Germany	Hehe	Landesanstalt für Landwirtschaft Institut für Pflanzenbau und Pflanzenzüchtung	21/11/25
10	<i>Hordeum sativum</i>	Italy	Bop	Azienda agricola Frè di Raviola Giuseppina	12/08/25
11	<i>Lactuca sativa</i>	Czech Republic	Listonoh	Marek Kvapil	6/01/23
12	<i>Phaseolus coccineus</i> L.	Slovenia	Šurk	EKOSEMENA	2/12/23
13	<i>Phaseolus vulgaris</i> L.	Czech Republic	Beefy Resilient Grex	Marek Kvapil	22/09/25
14	<i>Phaseolus vulgaris</i> L.	Czech Republic	Mozaika	Marek Kvapil	15/01/26
15	<i>Phaseolus vulgaris</i> L.	Czech Republic	Lofthouse Landrace Beans	Marek Kvapil	3/03/22
16	<i>Phaseolus vulgaris</i> L.	Slovenia	KIS Bogo	Kmetijski inštitut Slovenije, Infrastrukturni Center Jablje	22/12/23

17	<i>Phaseolus vulgaris</i> L.	Slovenia	KIS Deodat	Kmetijski inštitut Slovenije, Infrastrukturni Center Jabolje	22/12/23
18	<i>Phaseolus vulgaris</i> L.	Slovenia	Klošter	EKOSEMENA	11/07/25
19	<i>Phaseolus vulgaris</i> L.	Slovenia	KAPELAN	EKOSEMENA	11/07/25
20	<i>Pisum sativum</i> L.	Germany	Sirki	Gzpk	14/07/25
21	<i>Raphanus sativus</i> L.	Austria	Roulette	Arche Noah	26/08/25
22	<i>Raphanus sativus</i> L.	Poland	Axona	GLOBALGRASS sp. z o.o.	8/04/25
23	<i>Secale cereal</i> e L.	Austria	Berglandroggen	Veronika Müllner	2/06/22
24	<i>Secale cereal</i> e L.	Germany	Dodo	Werner Vogt-Kaute	11/04/22
25	<i>Secale cereal</i> e L.	Germany	Baldachin	Landbauschule Dottenfelderhof e.V.	12/05/22
26	<i>Secale cereal</i> e L.	Germany	Artemis	Herrn Werner Vogt-Kaute	31/01/25
27	<i>Solanum lycopersicum</i>	Czech Republic	Valouny	Marek Kvapil	3/03/22
28	<i>Solanum lycopersicum</i>	Czech Republic	Vejce ptáka Ohniváka	Marek Kvapil	3/03/22
29	<i>Solanum lycopersicum</i>	Czech Republic	Red punk	Marek Kvapil	15/01/26
30	<i>Solanum lycopersicum</i>	Slovenia	Ronja	EKOSEMENA	9/02/26
31	<i>Solanum melongena</i>	Czech Republic	Kvapík	Marek Kvapil	3/03/22
32	<i>Triticum aestivum</i>	Austria	Wildschönauer Sommerweizen	Emil Platzer	8/06/22
33	<i>Triticum aestivum</i>	Denmark	Mariagertoba	Landsorten	30/06/22
34	<i>Triticum aestivum</i>	Denmark	Popkorn	Landsorten	30/06/22
35	<i>Triticum aestivum</i>	France	Pop Orvilliers	Ferme d'Orvilliers	25/01/24
36	<i>Triticum aestivum</i>	Germany	Convento C	Landbauschule Dottenfelderhof e.V.	2/02/22

37	<i>Triticum aestivum</i>	Germany	Convento E	Landbauschule Dottenfelderhof e.V.	2/02/22
38	<i>Triticum aestivum</i>	Germany	Brandex	Landbauschule Dottenfelderhof e.V.	2/02/22
39	<i>Triticum aestivum</i>	Germany	Liocharls	Landbauschule Dottenfelderhof e.V.	2/02/22
40	<i>Triticum aestivum</i>	Germany	Perfimalina	Herrn Malte Kraus	8/05/24
41	<i>Triticum aestivum</i>	Italy	Oroset	Arcoiris s.r.l.	18/08/25
42	<i>Triticum aestivum</i>	Italy	Furat tenero Li Rosi	Azienda agricola Terre frumentarie di Giuseppe Li Rosi	9/10/25
43	<i>Triticum aestivum</i>	Italy	Furat tenero Floriddia	Azienda agricola biologica Rosario Floriddia	9/10/25
44	<i>Triticum aestivum</i>	Italy	Furat tenero Piceno	Azienda agricola Leonardo Pazzi-Pierluigi Valenti	10/10/25
45	<i>Triticum durum</i>	Italy	Bosco dei frumenti	Iacoviello Liliana	18/08/25
46	<i>Triticum durum</i>	Italy	Evoldur13A	Arcoiris s.r.l.	29/08/25
47	<i>Triticum durum</i>	Italy	Carosella Lucana	A.L.S.I.A. – Agenzia Lucana di Sviluppo ed Innovazione in Agricoltura	10/09/25
48	<i>Triticum durum</i>	Italy	Evoldur Terre Frumentarie	Azienda agricola Terre frumentarie di Giuseppe Li Rosi	9/10/25
49	<i>Triticum durum</i>	Italy	Furat duro Floriddia	Azienda agricola biologica Rosario Floriddia	9/10/25
50	<i>Triticum durum</i>	Italy	Evoldur Fabbri	Arcoiris s.r.l.	10/10/25
51	<i>Triticum durum</i>	Italy	Evoldur Cori 53	Arcoiris s.r.l.	10/10/25
52	<i>Triticum durum</i>	Italy	Furat duro Petacciatto	AgriBio Pantasia di Petacciato Mariangela	20/02/26
53	<i>Vicia faba</i> L. – Fava bean	Germany	Detta	Werner Vogt-Kaute	11/04/22
54	<i>Vicia faba</i> L. – Fava bean	Portugal	Marro	Sementes Vivas	8/06/25
55	<i>Vicia faba</i> L. – Fava bean	Portugal	Aurora Violeta	Sementes Vivas	8/06/25
56	<i>Zea mays</i>	Austria	Pernath	Arche Noah	11/07/25
57	<i>Zea mays</i>	Czech Republic	Malované hory	Marek Kvapil	6/01/23
58	<i>Zea mays</i>	Germany	Almito	Landbauschule Dottenfelderhof e.V.	2/02/22

59	<i>Zea mays</i>	Germany	Bogdan	Landbauschule Dottenfel derhof e.V.	2/02/22
60	<i>Zea mays</i>	Germany	Tambudzai	Bayern	10/02/22
61	<i>Zea mays</i>	Germany	Weihsteph 2	Bayern	10/02/22
62	<i>Zea mays</i>	Germany	Weihsteph 3	Landesanstalt für Landwir tschaft Institut für Pflanze nbau und Pflanzenzüchtu ng	10/02/22
63	<i>Zea mays</i>	Germany	Evolino	Firma Getreidezüchtung P eter Kunz Deutschland, g emeinnützige GmbH	1/06/22
64	<i>Zea mays</i>	Germany	Rote Gruberin	Landesanstalt für Landwir tschaft Institut für Pflanze nbau und Pflanzenzüchtu ng	21/11/25
65	<i>Zea mays</i>	Germany	Kya	Landesanstalt für Landwir tschaft Institut für Pflanze nbau und Pflanzenzüchtu ng	21/11/25
66	<i>Zea mays</i>	Poland	Hańcza	Pietrzak sp. z o.o. sp. k.	5/12/23
67	<i>Zea mays</i>	Poland	Ukiel	Pietrzak sp. z o.o. sp. k.	27/11/24
68	<i>Zea mays</i>	Poland	Isąg	Pietrzak sp. z o.o. sp. k.	27/11/24
69	<i>Zea mays</i>	Poland	Notyst	Pietrzak sp. z o.o. sp. k.	27/11/24

Annex 2. Questions of LiveSeeding Workshop

Baseline

What are the differences between seed production of OHM and standard varieties?

What are the specific characteristics of OHM seed production?

Imagine you are an OHM seed producer...

1. How would you begin OHM seed production?
2. What short-term and long-term goals would you set for yourself?
3. What sources of information would you turn to (people, publications, organizations)?
4. In your view, what are the main challenges of working with heterogeneous materials in terms of: Seed quality, managing diversity during seed multiplication, Managing diversity during seed processing
5. What do you consider the most crucial step in ensuring both quality and diversity in OHM seed production? Why?
6. As an inspiration, can you name any examples (local or international) where OHM seed production has worked well in your opinion? What made it successful?

Your input is very valuable to us

Do you know any OHM breeders or seed producers? (Their name & email)

Are you aware of any relevant literature on this topic? Please share it here:

Would you be interested in participating in a follow-up interview on this topic?
Please write here your name and email:

Annex 3: LiveSeeding survey questions

- **General questions:**
 - Do you have practical experience with OHM seed production?
 - Which part of the OHM seed production are you involved in?
 - What kind of crop species do you deal with?
- **Seed quality management**
 - How do you control seed quality in your OHM seed production?
 - Did you identify any problem regarding the OHM seed quality?
 - What are the most important processes to ensure high-quality OHM seed?
 - Which parameters do you find more important in the case of OHMs compared to homogeneous varieties? Why? (Germination, physical purity, moisture content, seed health)
- **Diversity management**
 - **Seed multiplication and maintenance**
 - How do you maintain your OHM? Do you have a recommendation or protocol?
 - In your opinion, what is the most critical step at OHM seed multiplication and maintenance?
 - How do you manage cross-pollination in heterogeneous populations, if relevant?
 - How many plants/replications are needed for population integrity?
 - How do you maintain intra-varietal diversity over generations?
 - How do you prevent unintentional genetic drift or narrowing?
 - **Seed processing and storage**
 - Which methods do you use for drying, cleaning, and sorting OHM seed?
 - Did you identify any problems regarding OHM seed processing and storage?
 - What differences did you find between the seed processing of OHM and homogeneous material?
 - How can selection bias be avoided during processing?