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# **Factors Driving Organic Seed Production and Cultivar Development for Europe's Organic Farming Sector**

## **Dissertation**

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## Summary

Europe's organic seed and breeding sector faces significant challenges but also presents promising growth opportunities. The organic seed market in Europe remains underdeveloped due to unresolved technical and socio-economic issues. There is a persistent demand for non-organic plant reproductive material, primarily because of the inadequate supply of sufficient organic seed and planting materials that meet the diverse requirements for organic growing conditions. When farmers continuously use non-organic seeds, it diminishes the incentive to develop seeds and cultivars suited for organic cultivation. Financial resources for breeding varieties tailored to various European farming conditions are limited, and organic seed production is often more expensive than conventional seed production, requiring higher investments.

Despite these hurdles, there are promising prospects for the future. The EU's organic seed market has been experiencing steady growth, driven by the increasing demand for organic products. The EU's Green Deal and the Farm to Fork strategy aim to convert 25% of farmland to organic by 2030, creating a significant market opportunity. Additionally, the EU Organic Regulation 2018/848 highlights the importance of organic seeds and sets a deadline to phase out derogations that allow non-organic seed usage by the end of the year 2036.

This thesis explores the barriers and opportunities for expanding the organic seed and breeding sector in Europe, focusing on seed suppliers, breeders, and policy frameworks. It contributes to the research by addressing a critical gap in the literature and offers new insights into an understudied area.

An analysis of seed supplier's and breeders' perspectives reveals that actors face several challenges in providing organic seed and suitable varieties for the organic farming sector in Europe. While smaller companies may encounter financial difficulties and a higher need in training, larger companies seem to encounter technical and organisational challenges. In the context of breeding for the organic farming sector the research shows that mainly very small companies, non-profit initiatives and research institutes perform organic breeding or participatory breeding approaches with a strong focus for diversity. Despite these challenges, there are opportunities for growth. Phasing out derogations for non-organic seeds and providing subsidies could encourage organic seed use. Companies that offer both organic and conventional seeds can navigate market fluctuations more effectively. Addressing technical and regulatory challenges will be key to developing a robust organic seed market that supports sustainable agriculture and meets consumer expectations.

The analysis of Germany's organic cereal seed sector reveals growth, with more farmers adopting organic seeds and reducing reliance on non-organic seeds. Germany's national organic database, [organicXseeds.de](http://organicXseeds.de), could improve market transparency and influence farmer behaviour.

A study of ten EU member states highlights that multi-actor approaches can

improve governance and foster collaboration. Effective policies should focus on transparency, accountability, and participation, involving local stakeholders to ensure policies align with on-the-ground realities.

In conclusion, the thesis suggests that improved governance, greater stakeholder involvement, and consistent policies are key to advancing the organic seed and breeding sector in Europe.

## Zusammenfassung

Europas ökologischer Saatgut- und Züchtungssektor steht vor großen Herausforderungen, bietet aber auch vielversprechende Wachstumschancen. Der Markt für ökologisches Saatgut in Europa ist aufgrund ungelöster technischer und sozioökonomischer Probleme nach wie vor unterentwickelt. Es besteht eine anhaltende Nachfrage nach nicht-ökologischem Pflanzenvermehrungsmaterial, vor allem wegen des unzureichenden Angebots an ökologischem Saat- und Pflanzgut, das den vielfältigen Anforderungen des ökologischen Anbaus gerecht wird. Durch den fortlaufenden Einsatz von nicht-ökologischem Saatgut, sinkt der Anreiz, geeignetes Saat- und Pflanzgut für den ökologischen Sektor zu entwickeln. Die finanziellen Mittel für die Züchtung von Sorten, die auf die verschiedenen Anbaubedingungen in Europa angepasst sind, sind begrenzt, und die ökologische Saatguterzeugung ist oft teurer als die konventionelle Saatguterzeugung und erfordert höhere Investitionen.

Trotz dieser Hürden gibt es vielversprechende Aussichten für die Zukunft. Der Markt für ökologisches Saatgut in der EU verzeichnet ein stetiges Wachstum, das auf die steigende Nachfrage nach ökologischen Produkten zurückzuführen ist. Der „Green Deal“ der EU und die „Farm to Fork“-Strategie zielen darauf ab, bis 2030 25 % der landwirtschaftlichen Nutzfläche auf ökologischen Landbau umzustellen, was eine bedeutende Marktchance darstellt. Darüber hinaus unterstreicht die EU-Öko-Verordnung 2018/848 die Bedeutung von ökologischem Saatgut und setzt eine Frist für die schrittweise Abschaffung von Ausnahmegenehmigungen, die die Verwendung von nicht-ökologischem Saatgut erlauben, bis zum Ende des Jahres 2036.

Die vorliegende Dissertation untersucht die Hindernisse und Chancen für die Ausweitung des ökologischen Saatgut- und Züchtungssektors in Europa und konzentriert sich dabei auf Saatgutanbieter, Züchter und politische Rahmenbedingungen. Sie leistet einen Beitrag zur Forschung, indem sie eine kritische Lücke in der Literatur schließt und neue Einblicke in einen wenig untersuchten Bereich bietet.

Eine Analyse der Perspektiven von Saatgutproduzenten und -züchtern zeigt, dass die Akteure bei der Bereitstellung von ökologischem Saatgut und geeigneten Sorten für den ökologischen Landbau in Europa vor verschiedenen Herausforderungen stehen und unterschiedliche Sichtweisen darauf haben. Während kleinere Unternehmen mit finanziellen Schwierigkeiten und einem höheren Schulungsbedarf umgehen müssen, scheinen größere Unternehmen vor technischen und organisatorischen Herausforderungen zu stehen. In Bezug auf die Sortenentwicklung für den ökologischen Landbau zeigt die Untersuchung, dass hauptsächlich sehr kleine Unternehmen, gemeinnützige Initiativen und Forschungsinstitute ökologische Züchtung oder partizipative Züchtungsansätze mit einem starken Fokus auf Vielfalt betreiben. Trotz dieser Herausforderungen gibt es Möglichkeiten für Wachstum. Die Abschaffung von Ausnahmeregelungen

für nicht-ökologisches Saatgut und die Bereitstellung von finanziellen Förderinstrumenten könnten die Verwendung von ökologischem Saatgut fördern. Unternehmen, die sowohl ökologisches als auch konventionelles Saatgut anbieten, können Marktschwankungen besser abfangen. Die Bewältigung technischer und regulatorischer Herausforderungen wird der Schlüssel zur Entwicklung eines robusten Marktes für ökologisches Saatgut sein, der eine nachhaltige Landwirtschaft unterstützt und die Erwartungen der Verbraucher erfüllt.

Die Analyse des deutschen Öko-Getreidesaatgutsektors zeigt ein Wachstum, da mehr landwirtschaftliche Betriebe Öko-Saatgut verwenden und die Abhängigkeit von nicht-ökologischem Saatgut verringern. Deutschlands nationale Ökosaatgut Datenbank [organicXseeds.de](http://organicXseeds.de) könnte die Markttransparenz verbessern und das Verhalten der Landwirte hin zu einem höheren Ökosaatguteinsatz beeinflussen.

Eine Studie in zehn EU-Mitgliedstaaten zeigt, dass Multi-Akteurs-Ansätze die Rahmenbedingungen verbessern und die Zusammenarbeit fördern können. Eine wirksame Politik sollte sich auf Transparenz, Rechenschaftspflicht und Partizipation konzentrieren und lokale Interessengruppen einbeziehen, um sicherzustellen, dass die Politik mit den Realitäten der Interessensgruppen vor Ort übereinstimmt.

Zusammenfassend lässt sich sagen, dass verbesserte Rahmenbedingungen, eine stärkere Beteiligung der Interessengruppen und eine kohärente Politik der Schlüssel zum Fortschritt des ökologischen Saatgut- und Züchtungssektors in Europa sind.

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# 1. Introduction

As described by the Food and Agriculture Organization of the United Nations (FAO, 2009), organic agriculture is a holistic production management system that can promote and enhance agroecosystem health, including biodiversity, biological cycles, and soil biological activity. According to the International Federation of Organic Agriculture Movements (IFOAM Organics Europe, 2022), organic agriculture combines tradition, innovation, and science to benefit the shared environment and promote fair relationships and good quality of life for all involved. In Europe, the organic food market is continuously growing, driven by increasing consumer demand (Horrigan et al., 2002; Valero-Gil et al., 2023). The organically managed farmlands, the number of organic farms, and the global market size for organically grown foods have increased steadily over the last decades. By 2021, 15.6 million ha of agricultural land and 9.6% of the agricultural area in the European Union were managed organically by more than 380,000 producers (Willer et al., 2023). To make Europe's economy more sustainable and climate-neutral the European Commission launched the European Green Deal (European Commission, 2020; Paull, 2024). The Farm to Fork strategy is one of the initiatives under the European Green Deal which aims for more sustainable food systems, and by increasing the use of renewable energy. One of the main objectives of the Farm to Fork strategy is to raise the area of land devoted to organic farming in the European Union (EU). The European Commission has set a target of at least 25% of the EU's agricultural area being organically managed by the year 2030. This goal is intended to promote sustainable food production and consumption, and to help mitigate the impact of agriculture on the environment and climate change (European Commission, 2020; Paull, 2024). Also, the Farm to Fork strategy aims to support research and innovation on organic farming, to improve the knowledge base, and to develop new organic farming practices and technologies. Current projections estimate that organic farming area will only reach about 15% by 2031, assuming growing demand and continuing policy support. To reach 25% organic farming area further incentives would be necessary (Eurostat, 2024). However, one of the main challenges for the organic agricultural sector to upscale the farming area is to comply with the principles of organic agriculture concerning health, ecology, fairness, and care, as formulated by the world umbrella organization for the organic sector the International Federation of Organic Agriculture Movements (IFOAM Organics International) (Luttikholt, 2007). IFOAM Organics International is a private body representing farmers, processors, retailers, certifiers and traders. The mission of IFOAM Organic International concerning the integrity of organic

Objectives of the European Commission:

At least 25% of the European Union's agricultural land under organic farming and a significant increase in organic aquaculture by 2030.

farming is to ensure the credibility and transparency of organic products and practices worldwide (IFOAM Organics Europe, 2022; Leu, 2020)

## 1.1 Legal Framework

In Europe, consumers generally expect organic products to be produced using inputs that comply with the organic production standard and are free of chemical pesticides, mineral fertilisers and genetically modified organisms (GMO) (Martini et al., 2024; Varaldo et al., 2022; Von Meyer-Höfer et al., 2015). For its credibility, consumers' trust, and transparency, the organic sector is trying to close the entire production chain (Lammerts van Beuren et al., 2003). Article 5 of the Organic Regulation 2018/848 (European Union, 2018) describes the "general principals" of organic production. According to Article 5, "Organic production is a sustainable management system that is based on the following general principles: (a) respect for nature's systems and cycles and the sustainment and enhancement of the state of the soil, the water and the air, of the health of plants and animals, and of the balance between them; [...] (e) ensuring the integrity of organic production at all stages of the production, processing and distribution of food and feed [...] (g) the restriction of the use of external inputs; where external inputs are required or the appropriate management practices and methods referred to in point (f) do not exist, the external inputs shall be limited to: (i) inputs from organic production; in the case of plant reproductive material, priority shall be given to varieties selected for their ability to meet the specific needs and objectives of organic agriculture; (ii) natural or naturally-derived substances; (iii) low solubility mineral fertilisers;". According to the Organic Regulation 2018/848, organic farmers must use organically produced seed and planting material when available (European Union, 2018). As illustrated in Figure 1 there are several steps to be taken from breeding to certified organic seed production. To commercialize a plant variety in Europe, it must be registered by the seed authority of an EU Member State and listed either in a national seed variety catalogue or in the common EU variety catalogue maintained by the Community Plant Variety Office (CPVO, 2025). Once a variety is released, commercial seed production can begin using "breeder's seed," which is provided by the variety owner. To ensure an adequate supply of seeds, an intermediate step known as "basic seed" production is undertaken. In the case of agricultural crops, this basic seed is then given to farmers, who cultivate it under contract to produce certified seed that can be sold to other farmers (ISTA, 2025). If the seed production occurs under certified organic conditions, the resulting seeds are approved as certified organic seed. Additionally, in some EU countries,

Overarching aim of the Organic Regulation 2018/848:  
Provide consistent organic production guidelines in the European Union.

varieties are tested after registration to determine their suitability for various growing conditions, including their adaptability to organic farming practices.

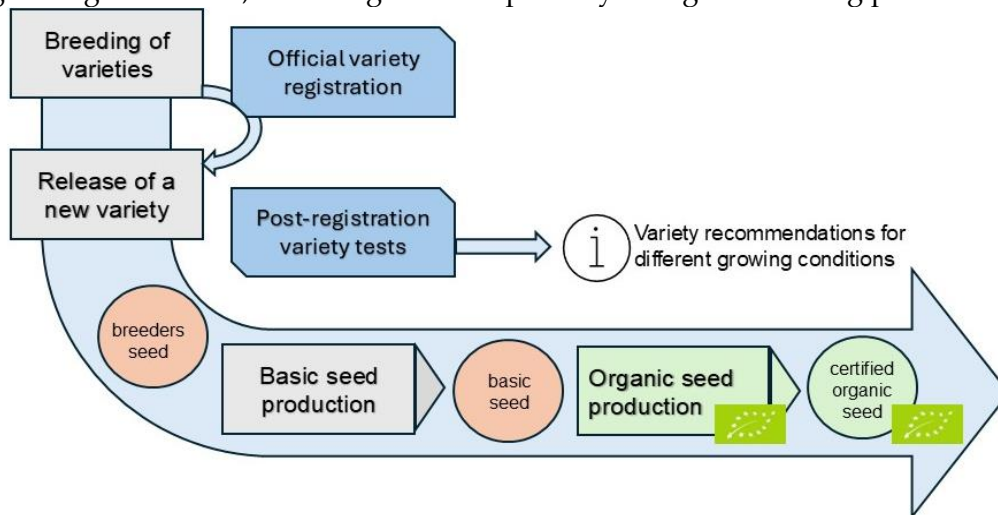


Figure 1 Flowchart with steps from variety breeding to certified organic seed production

Organic farmers are obliged to use organic seed when a suitable variety is available (European Union, 2018). Figure 2 illustrates the process how the information of organic seed availability is communicated via national organic seed databases.

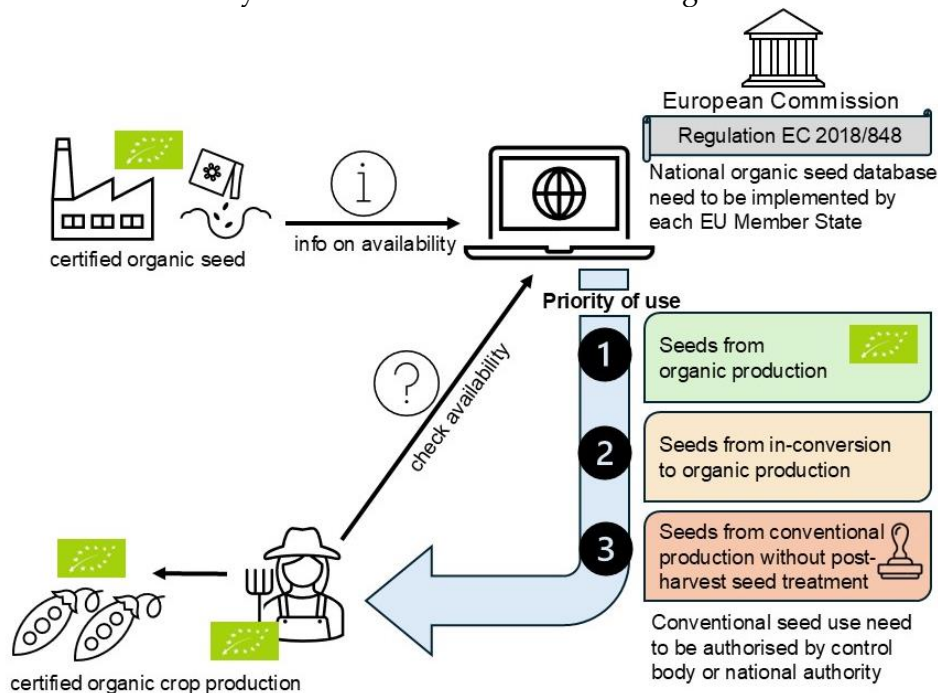


Figure 2 Flowchart with information flow on availability of organic seeds through national seed databases and priority of seed use by organic farmers

Through a “priority of use” farmers must use organic seed over seeds that derive from production under “conversion to organic”. If no suitable organic or in-conversion seed is available in the national organic seed database, framers can ask for a derogation to be granted by their organic control body or designated control authority (European Union, 2018) (Figure 2). In accordance with Article 26, paragraph 1 of the Regulation (EC) No 2018/848 (European Union, 2018), “each member state shall provide a database or a system for the listing of organic and in-conversion seeds, excluding seedlings but including seed potatoes, which is available on its territory”. The implementation of the amendment regulation (EC) No 1452/2003 (European Union, 2003) necessitated the establishment of national databases, which came into effect on 1 January 2004. Since then, various iterations of these databases have been developed at the EU Member State level. The implementation of these databases varies from a simple PDF or Excel file to an elaborated real-time online application (Solfanelli, Ozturk, Orsini, et al., 2022). All database entries on the availability of organic seed and in-conversion seed constitute the legal basis for the authorisation of derogations on the use of non-organic seed (European Union, 2018). The process for obtaining a derogation can vary depending on the country and the specific regulations in place, but generally, a farmer must demonstrate that no suitable organic seed is available. They must also provide detailed information about the crop in question, including the reasons why organic seed is not suitable (European Union, 2018). The decision to grant a derogation is usually made by the certifying body that oversees organic farming in a particular country. Overall, the derogation process is in place to provide flexibility for farmers, but it is not necessarily an easy process to obtain a derogation, and it is important for farmers to understand the specific regulations and requirements in their country (Fuss et al., 2020). However, the process of obtaining a derogation varies between countries. While in some countries a derogation request is requested in a fully computerized system, some countries still rely on paper forms (Solfanelli, Ozturk, Orsini, et al., 2022). Table 1 illustrates when a derogation needs to be requested by a farmer.

Table 1 Overview of breeding and seed production under conventional or organic conditions and the resulting seed and the need to request a derogation on non-organic seed in commercial organic farming in the EU, based on (European Union, 2018)

Breeding conditions	Seed multiplication conditions	Resulting seed	Derogation needed in commercial organic farming
conventional	conventional	Conventional seed	yes
conventional	certified organic	Organic seed	no
certified organic	certified organic	Organic seed	no

The EU Organic Regulation 2018/848 outlines specific requirements for organic plant reproductive material (PRM), including seeds. For annual crops, the mother plant must be under certified organic production for at least one generation. For biennial or perennial crops, the requirement is for at least one generation during two growing seasons. However, the breeding process itself does not necessarily have to occur under organic conditions; it is not obligatory (European Union, 2018). Back in 2003, the EU Regulation 2092/91 (European Union, 1991) for organic agriculture aimed at closing the organic production chain. "The EU regulation 2092/91 for organic agriculture will allow no more general derogation in the use of conventionally propagated seed from 2004 onwards. Only the use of organically propagated seed will be permitted for those listed crops of which sufficient varieties and quantities are already available." (Lammert van Beuren, 2003). The objective of phasing out the derogations for the use of non-organic seeds has been suspended as the use of non-organic seeds is still allowed by Council Regulation (EC) No 834/2007 of 28 June 2007 on organic production and labelling of organic products (European Union, 2007), which repealed Regulation (EEC) No 2092/91. While the exact reason for prolonging the use of non-organic seeds in 2004 is not explicitly stated in literature, it's likely that this decision was made due to the continued shortage of organic seeds and to support the growth of the organic sector while working towards increasing organic seed availability. Nowadays, based on a lack of supply, European organic farmers still depend on a "derogation procedure" of using non-organic seeds and planting material (Solfanelli, Ozturk, Dudinskaya, et al., 2022).

Regulation EC 2018/848 further categorises crops or crop sub-groups into three distinct classes, empowering EU Member States to implement varied standards for different crops, provided that the minimum requirements of the regulation are adhered to (European Union, 2018). This approach can be seen as predicated on the recognition that different crops and Member States possess distinct characteristics and circumstances, necessitating a tailored approach to the phasing-out of the use of non-organic seed in organic farming. It can be assumed that the objective is to ensure that this process is both practical and feasible for farmers and seed companies. For category I crops, as defined in Part I of Annex II, article 1.8.5.6 of Regulation (EU) 2018/848, as amended by Delegated Regulation (EU) 2020/1794 (European Union, 2020a), the availability of sufficient quantities of organic seed and propagating material is ensured. Consequently, the granting of derogations for category I crops is not permissible. Exceptions to this regulation may be permitted under Article 1.8.5.1 "(d) if the cultivar is requested for research; testing in small-scale field trials; cultivar conservation or product innovation" (European Union, 2018, 2020a). An overview of crop classifications to category I crops is available on the website of the European Router database ([www.seed4organic.eu](http://www.seed4organic.eu)). This overview is subject to yearly updates. As of July 2024, a total of nine out of 29 countries (including the United Kingdom and Switzerland) had listed crops or sub-groups of crops in category I (European Router Database, 2024). The given

overview “only considers the species-level, in some cases only the genus-level, whereby the competent authorities may include species, subspecies or varieties (grouped if applicable) in the category I list” (European Router Database, 2024). The number of species or genera varies between 89 in Switzerland, 75 in the Netherlands, 49 in Denmark, 37 in France, 24 in Belgium, 20 in Germany, 14 in Luxembourg, 12 in Spain, and 3 in Sweden (European Router Database, 2024). Nevertheless, it should be noted that the total number of crops included in a national list does not necessarily reflect all the relevant details. For example, some countries include various ornamental species (for instance, Switzerland), while other countries, such as Germany employs a methodology that sub-divides each single crop species. For category II crops, a case-by-case decision is to be made, with single derogations granted upon the provision of justification, as outlined in Article 1.8.5.1 of Part I Annex II of Regulation (EC) No 2018/848 (European Union, 2018). General authorisations (also known as category III crops) may be granted in instances where the availability of organic plant reproductive material is limited to a specific number of varieties. Several EU member states have established national annexes listing species for which general derogations can be granted. For vegetative propagation material, general derogations may be given as long as organic markets are not established nationally, due to the profound undersupply of organic propagation material for many crop species (European Union, 2018).

The organic seed market in Europe is still relatively small compared to the overall (conventional) seed market and faces several challenges. With regional and crop-specific differences, organically propagated seed and planting material is rather rare in Europe. Many crop varieties are not yet available from organic multiplication (Solfanelli, Ozturk, Dudinskaya, et al., 2022). A comparative analysis reveals that farms situated in the

southern and eastern regions of the EU exhibit the lowest adoption of purchased certified organic seeds, with approximately 42.7% and 34.7%, respectively. In contrast, farms located in the northern and central regions of the EU demonstrate higher utilisation rates, with approximately 55.4% and 71.1%, respectively (Solfanelli, Ozturk, Dudinskaya, et al., 2022). This can make it difficult for farmers to find the seeds they need (Orsini et al., 2020). With its entry into force on 1st of January 2022, the organic Regulation EC 2018/848 set out a clear target to phase out the use of non-organic seeds (European Union, 2018). From 1st of January 2037 onwards, only organically multiplied plant reproductive material shall be used. The regulation applies to all organic crops, including both annual and perennial crops, and includes vegetative propagating material and in-conversion seeds (Art. 26, EC Regulation No 2018/848). However, phasing out the use of non-organic plant

The objective of Article 26,  
EC 2018/848

Phasing out the use of non-  
organic seed and planting  
material by the end of 2036.

reproductive material by the end of 2036, while increasing the organic farming area by up to 25% by 2030 may cause a conflict. It remains unclear what may happen if the supply of organic seed and planting material does not keep pace with the increasing organic farming area in Europe. According to Döring et al. (Döring et al., 2012) a high level of non-organic seed use hinders the development of the organic seed sector. When farmers use non-organic seed in organic farming, it reduces the demand for organic seed, making it less financially attractive for seed companies to invest in the development and production of organic seed. In the past, an insufficient volume of seed was produced under certified organic conditions. Besides the need to increase organic seed production, the research of Orsini et al. (Orsini et al., 2020) shows that the availability of cultivars, suitable for organic production, plays an important part in farmers' choice of seed. This was already identified by Lammerts van Bueren et al. (Lammerts Van Bueren et al., 2011) who see a need to breed crop varieties suitable for organic farming. However, due to a low number of varieties tested under organic conditions, it remains unclear for many farmers which varieties are agronomically most suitable for their organic production. Limited research and development in organic plant breeding, can limit the development of new crop varieties suited to organic farming. Thus, Lammerts van Bueren et al. (Lammerts Van Bueren et al., 2018) state, that developing suitable varieties is a key challenge for the organic sector. Varriere et al. (Varriere et al., 2019) state to embrace the full potential of organic farming it is necessary to better adapt varieties to the specific needs of the organic sector.

## 1.2 Organic Seed Market

The organic seed sector in Europe is considered a relatively fragmented market (Padel et al., 2021). There are many small and medium-sized companies that produce and supply organic seeds, as well as a smaller number of larger companies. Farmers and seed producer may struggle to navigate the market and make informed purchasing decisions, due to the lack of transparency and regulatory differences across countries in Europe (Raaijmakers & Schäfer, 2019).

Additionally, the fragmentation of the market can make it more difficult for new actors to enter, as they may face challenges in achieving economies of scale and competing with established companies. It could also make it harder for seed suppliers to predict and plan for the demand for organic seed. The process of seed propagation and multiplication under certified organic conditions is subject to a specific set of certifications and regulations, which can prove challenging and costly to adhere to (Raaijmakers & Schäfer, 2019). These factors can deter investment in

The status quo:

The frequent use of non-organic seed and planting material impedes the development of the organic seed and breeding sector.

organic seed production and breeding activities by seed companies. Seed suppliers may question the viability of engaging in organic seed production, as a lack of demand for organic seeds may impede investment, as seed producers are unable to cover the production costs. However, the demand for organic seed and suitable varieties may be increasing, driven by regulations that aim to phase out the use of non-organic seed and planting material (European Union, 2018). The limited availability of organic seed can make it difficult for farmers to switch to using organic multiplied seed or for seed companies to invest in organic seed production (Raaijmakers & Schäfer, 2019). This can create a supply-demand paradox, where seed suppliers may question whether starting organic seed production is worth it if there is little demand (BFICSS, 2014). Concerns have been raised about transparency and a lack of a “level playing field” in the organic seed market in Europe. For instance, some market actors have reported difficulties obtaining information about potential markets as not all EU Member State authorities publish their yearly derogation reports on non-organic seed use (Raaijmakers & Schäfer, 2019). Only a few European countries separate between conventional and organic seed multiplication areas in their statistics (Raaijmakers & Schäfer, 2019). Additionally, some actors have raised concerns about a lack of consistency and accountability in organic seed certification standards across different countries and difficulties in entering national seed databases which can create challenges for companies that operate in multiple countries (Raaijmakers & Schäfer, 2019; Solfanelli, Ozturk, Orsini, et al., 2022).

To support the development of the organic seed sector, some countries developed policy measures and seed provisions at the national level (Fuss et al., 2020). Back in 2004, the first expert group on organic seed was initiated in the Netherlands. The mandate of this expert group was to advise the national competent authority to implement provisions that foster the production and uptake of organic seed in the Netherlands. Implemented provisions included the establishment of a decision

The Dutch approach:  
Implementation of national policy measures and provisions to promote the production and uptake of organic seed and planting material.

framework for a “non-derogation list” (category I) including a first evaluation of crops for which sufficient organic seed was available to be categorised in the category I list of the Netherlands. Another example of an organic seed provision is a fixed annual date (before 1st February) by which farmers in the Netherlands must order organic seed potatoes (Fuss et al., 2020). The succeeding concept of organic seed expert groups was implemented by several other European member states. At present organic (seed) expert groups exist in Austria, Belgium, Denmark, France, Germany, Italy, Latvia, the Netherlands, United Kingdom, Sweden, and Switzerland (Fuss et al., 2020). To offer organic farmers a better overview of the

availability of seed from organic multiplication, the Research Institute of Organic Agriculture (FiBL) of Germany and Switzerland developed a database tool (OrganicXseeds, 2025). This tool was accepted by the authorities and became the official national database on organic seed in Germany and Switzerland. In the following years, the online application was adopted by further EU Member States authorities. Currently, the OrganicXseeds.com tool constitutes the official organic seed database in the countries Belgium, Denmark, Germany, Iceland, Ireland, Lithuania, Luxemburg, the Netherlands, Switzerland, Sweden, United Kingdom (OrganicXseeds, 2025). Additionally, the Danish organic seed expert group has established an organic seed provision known as the "equivalent variety list." This provision is based on the understanding that multiple varieties are often available in the market for specific marketing channels. The creation of this list was guided by field trials of organic varieties, as well as input from farm advisors and variety experts. If a particular variety is unavailable due to a lack of organic certification, an alternative from the equivalent varieties list must be chosen (Fuss et al., 2020). However, the concept of equivalent varieties has not been widely adopted by many other EU Member States, as it has faced challenges from certain stakeholders. According to the International Union for the Protection of New Varieties of Plants (UPOV), a variety is defined by three criteria: "distinctness, uniformity, and stability" (UPOV, 2002). Since the "distinctness" of a variety excludes the notion of "equivalent" varieties, this definition has raised concerns regarding the concept's validity. To promote the production and uptake of planting material for fruit trees, a pre-ordering provision with a period of 12 months was introduced in Germany and later taken up by the Netherlands and South Tyrol (Italy). According to these provisions, farmers are required to order their saplings in advance with a minimum ordering notice of 12 months before planting. Minimum quality criteria and a list of recommended cultivars and clones have also been developed (Fuss et al., 2020). The European Consortium of Organic Plant Breeding (ECO-PB) attempted to address the challenges posed by the lack of what could be described as a "level playing field" in the organic seed and breeding sector across Europe. ECO-PB is a network dedicated to supporting the production and use of organic seeds and organic bred varieties. In the past, it played a significant role in organizing workshops to address challenges and opportunities in organic plant breeding and seed regulation across Europe (Lammerts van Bueren & Wilbois, 2003). In 2007, ECO-PB co-organised a symposium on "genotype-environment interaction, breeding strategies, selection criteria, and participatory breeding approaches for organic and sustainable, low-input agriculture" (Lammerts van Beuren et al., 2007). In 2013, a European workshop on organic seed regulation, organized by ECO-PB, took place in Brussels, Belgium (ECO-PB, 2013). This event provided a platform for experts and stakeholders to exchange knowledge and contribute to the development of organic seed regulations in Europe.

### 1.3 Research Framework

In 2017, the project LIVESEED received funding from the European Union’s Horizon 2020 research and innovation programme and by the Swiss State Secretariat for Education, Research and Innovation (SERI) (LIVESEED, 2017). The LIVESEED project (2017 – 2021) was coordinated by the European umbrella organisation for organic food and farming (IFOAM Organics Europe) with FiBL Switzerland (Research Institute of Organic Agriculture) for scientific coordination and consists of 35 partners and 14 third linked parties from 18 European countries, with a budget of around 10 Mio €. LIVESEED aimed to establish a “level playing field” with fair marketing conditions in the organic seed market across Europe, improve the competitiveness of the organic seed and breeding sector, and encourage greater use of organic seeds by farmers (Messmer et al., 2018). To reach the ambitious aims, the project developed improved guidelines for cultivar testing and strategies for ensuring seed health. Innovative breeding approaches suited to organic farming were elaborated and socio-economic aspects relating to the use and production of organic seed and their interaction with relevant (EU) regulations investigated. LIVESEED followed an interdisciplinary and multi-actor approach with engagement of various stakeholder groups (Figure 3).

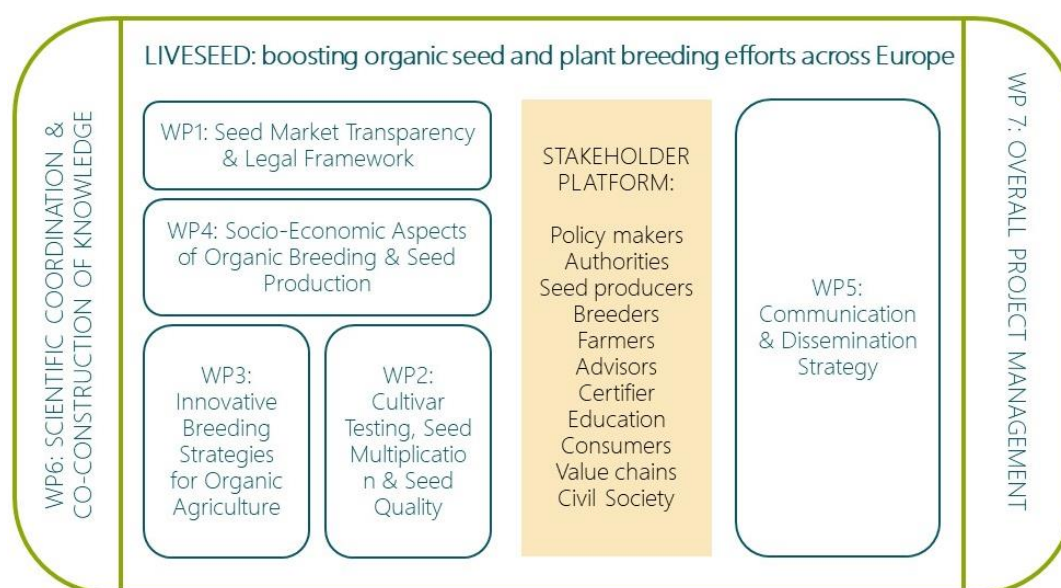


Figure 3: Functional structure of the LIVESEED project (2017-2021) (Messmer, et al., 2021).

Peer to peer knowledge exchange on seed multiplication was achieved in cross-border visits. LIVESEED developed a novel seed health strategy integrating seed production, vitality, seed microbiome and seed treatment. A system-based breeding concept was developed putting breeding into a broader perspective including societal challenge to reach the sustainable development goals (Lammerts Van Bueren et al., 2018). Experimental trials were implemented to improve

breeding, cultivar diversity and species mixtures. Organic breeding networks were established for various crops. Molecular markers are applied to identify resistance genes in various crops and next generation sequencing for elucidation of plant microbiome interaction (Messmer et al., 2021). Within WP4 on socio-economic aspects in breeding and seed production data were collected to develop an economic model for the organic seed value chain, which allows simulation studies on political or private sector interventions to overcome market failures (Winter et al., 2023). A cross-sector pool funding strategy for organic breeding, involving all partners from farmers to retailers, was developed (Winter, Grovermann, Aurbacher, et al., 2021)<sup>1</sup>. The study is based on a mixed method approach combining the assessment of qualitative data from a stakeholder dialogue with an analysis of quantitative farm survey data. Four success factors have been identified: a long-term commitment, a pool fund for organic cultivar development, awareness-raising on the importance of breeding, and a high level of transparency in the process (Winter, Grovermann, Aurbacher, et al., 2021).

Work package 1 (Figure 4), was led by FiBL Germany e.V.<sup>2</sup>. The objectives of the work package were to analyse the status quo and identify bottlenecks of organic seed production and use as well as the implementation of organic seed provisions in the different regions of the EU. Develop recommendations and tools for a

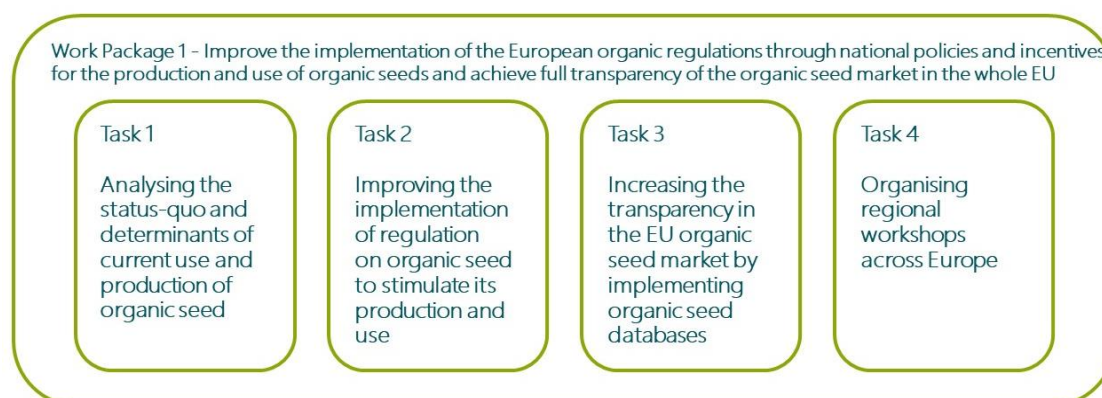


Figure 4 Description of work package 1 including tasks description within the LIVESEED project (LIVESEED, 2017).

common improvement of the organic seed supply and use on a national as well as on the EU level. Provide an IT tool for increasing transparency on available organic seed on a national as well as on the EU level. Assess national contexts to identify

<sup>1</sup> Co-authorship in: Winter, E., Grovermann, C., Auerbacher, J., Orsini, S., Schäfer, F., Lazzaro, M., Solfanelli, F., & Messmer, M. (2021). Sow what you sell: strategies for integrating organic breeding and seed production into value chain partnerships. *Agroecology and Sustainable Food Systems*, 45, 1500 - 1527. <https://doi.org/10.1080/21683565.2021.1931628>.

<sup>2</sup> The LIVESEED work package 1 was led by me, Freya Schäfer, on behalf of FiBL Germany e.V.



Furthermore, in task 1 a synopsis and analysis of national organic seed databases in place was conducted. For the analysis a large-scale online survey was initiated where organic farmers and seed supplier of organic seed and planting material were requested to share their experiences with the use of national organic seed databases in their respective country. An Information Systems Success Model was used as a framework of the evaluation (Solfanelli, Ozturk, Orsini, et al., 2022)<sup>1</sup>. The respondents assessed the Ease of use, Comprehension and Completeness of the databases. Based on 537 responses obtained from farmers, seed suppliers and certification bodies, the analysis revealed that the Completeness of the databases was evaluated as the most critical aspect. Interactive fully computerised databases should be preferred to the provision of static files as they positively influence perceived completeness. An in-depth analysis was developed from data of the German organic seed database [www.organicxseeds.de](http://www.organicxseeds.de). The methodology and results of this study are described in Chapter 3 from page 44 onwards of this thesis. A further analysis on the determinants for current use of derogations and demand for improved cultivars was assessed. The research showed that the situation of organic seed use is not consistent across European geographical regions and crop sectors (Orsini et al., 2020)<sup>2</sup>. In Central European regions, covered by the countries Austria, Belgium, France, Germany, Luxembourg, the Netherlands, and Switzerland, the organic seed use is higher than in other geographical regions in Europe. These results are further indicated by Solfanelli et al. (Solfanelli, Ozturk, Dudinskaya, et al., 2022). There are various factors that may affect farmers decision on using organic seed. Rey et al. (Rey et al., 2014) and Orsini et al. (Orsini et al., 2020) analysed that the marketing channel of the farmer may play an important role. If farmers are working in long supply chains tight margins may force to look for conventional seed that may be less expensive. While in shorter supply chains, such as in direct marketing or box-schemes marketing higher number of organic seed use were recorded (Orsini et al., 2020).

A seed supplier and breeder survey were conducted to better understand the bottlenecks of multiplying seed and breeding cultivars for the organic farming sector. The survey consisted of 43 questions on the business activities, such as breeding, seed multiplication and seed trade, types of crop groups handled, types of seeds handled (e.g. organic seed from conventional bred varieties, organic seed from organic bred varieties, seed from amateur and/or conservation varieties, conventional untreated and conventional treated seed). Companies were also asked about the size of company and the annual gross turnover from organic seed. Further

<sup>1</sup> Co-authorship in: Solfanelli F, Ozturk E, Orsini S, **Schäfer F**, Zanolli R. Improving the quality of national organic seed databases to increase the use of organic seed and propagation materials in Europe, *Computers and Electronics in Agriculture*, Volume 198, 2022, 107006, ISSN 0168-1699, <https://doi.org/10.1016/j.compag.2022.107006>.

<sup>2</sup> Co-authorship in: Orsini S, Costanzo A, Solfanelli F, Zanolli R, Padel S, Messmer MM, Winter E, **Schaefer F**. Factors Affecting the Use of Organic Seed by Organic Farmers in Europe. *Sustainability*. 2020; 12(20):8540. <https://doi.org/10.3390/su12208540>

questions on countries where organic seed is produced and countries where organic seed is sold were included. Respondents were asked to select those countries in which seed sales increased the most in the last three years. Limitations to the seed production, such as problems with pest and diseases were included as well as questions on bunt (*Tilletia*) in cereal production. Respondents could list the countries where they enter their seed offers in national seed databases. Those respondents who do not handle organic seed were asked several questions, e.g., if they are interested to become active in the organic seed sector and what was holding them back to become active. Further details on the survey are described in Chapter 2 from page 18 onwards of this thesis.

Within task 2 and 3 of work package 1, EU Member States authorities were encouraged to establish national organic seed expert groups, develop further policy measures, incentives, and national provisions. For this, an analysis of current implementation and best practices for an improved implementation of the regulation on organic seed was elaborated and published in two booklets. A collection of incentives was initiated.

To foster exchange and participation between actors of the organic seed sector and representatives on national and regional authorities, collaboration with 10 EU Member States was sought. Individual national visits to all 10 EU Member States took place and seven national and several European workshops were conducted. The methodology, results and discussion on this work is further described in Chapter 4 from page 70 onwards of this thesis.

To increase the transparency in the EU organic seed sector, in task 3, a centralized EU interface database, known as the “European Router Database” ([www.seeds4organic.eu](http://www.seeds4organic.eu)), has been developed to provide seed suppliers access to the national organic seed databases of all EU member states through a single login (Schäfer & Gatzert, 2023). The general concept of this interface was created with input and expertise from stakeholders in the European organic seed sector. Designed as a back-end system, the database facilitates information exchange between seed suppliers and national competent authorities (Figure 6). An inventory showed, that in 2023, 308 seed suppliers from 13 countries listed their organic seed offerings in the EU Router database. User analysis indicates that approximately 46% of registered seed suppliers list their organic seed offerings in multiple countries, significantly reducing the administrative burden of managing multiple databases with just one login. This system also enhances transparency within the organic seed sector. However, representatives from 17 European countries have not yet adopted the EU interface database (Schäfer & Gatzert, 2023).

At the end of the projects lifetime three policy briefs have been developed within or with the support of work package 1. The policy brief “The systems-based breeding approach” was developed as part of the work on “Innovative breeding strategies for organic agriculture (WP3)” (LIVESEED Policy Brief No. 1, 2021).

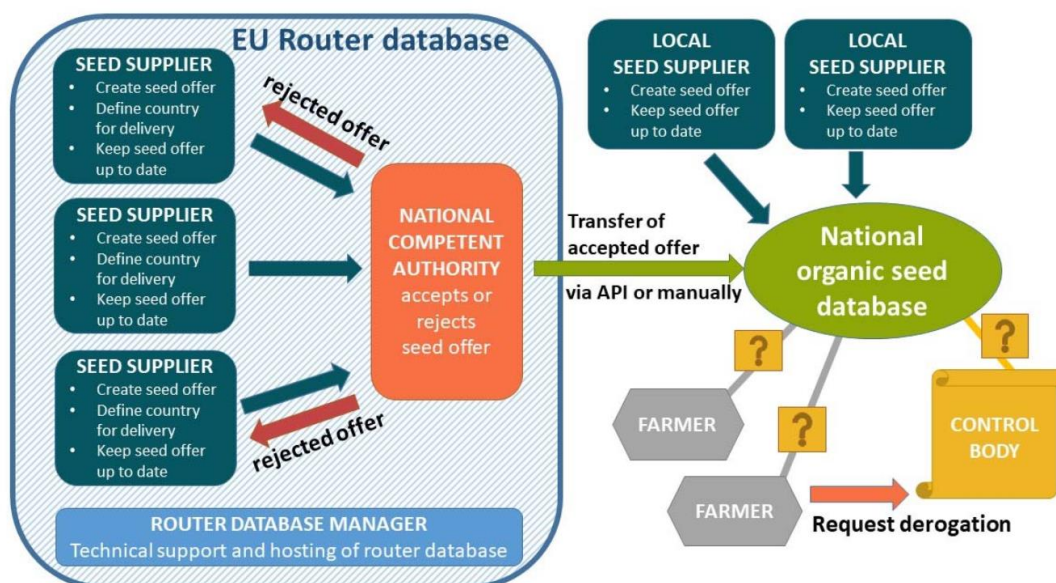


Figure 6 Flow chart of the EU router database. Data output into national organic seed database via Automated Programming Interface (API)<sup>1</sup> or manually.

This brief is aiming to inform and provide recommendations to policymakers based on integrating the model in different policies and instruments. The policy brief “Boosting organic seed production and use: An integrated analysis of policy impacts for three crop-country cases” provides recommendations based on research results (LIVESEED Policy Brief No. 2, 2021). The modelling exercise was carried out as part of the work on “Socio-Economic Aspects of Organic Breeding and Seed Production (WP4)”. The third policy brief “A national roadmap towards 100% organic seed by 2036” is part of a series aiming to inform policymakers on the key results of the LIVESEED project, and provide recommendations based on research results (LIVESEED Policy Brief No. 3, 2021). The recommendations and an infographic were developed as part of the work on Regulation & policy framework regarding production, use, and transparency of organic seed (WP1).

The LIVESEED project made several relevant contributions to the programme of the Organic World Congress 2021 and co-organised a pre-conference with the title “Seed Ambassadors: Building an International Network to Advance Organic Seed Systems” (OWC Pre-Conference, 2021).

<sup>1</sup> An automated programming interface (API) is a computing interface which defines interactions between multiple software intermediaries. The router database provides continuously, at least every 24 hours, all available data to APIs at national level. Data output is pre - defined in data set that include for example crop group, latin species name, name of cultivar, seed quality, country of delivery, delivery information, available quantity, ...

## **1.4 Motivation and Objectives**

The use of organic seed is a fundamental principle in organic farming (European Union, 2018). A suitable cultivar and healthy seeds set the foundation for successful plant production (Lammerts van Beuren et al., 2003). Moreover, consumers assume organic products to be produced by organic inputs (Martini et al., 2024; Valero-Gil et al., 2023; Von Meyer-Höfer et al., 2015). Solfanelli et al. (Solfanelli, Ozturk, Dudinskaya, et al., 2022) demonstrated that the supply of organic seeds and planting material is increasing in central Europe, while there is still a big gap in supply in other European regions. To maintain the integrity of the organic farming sector and to meet consumer expectations, there is a need to increase the supply of organic seeds and planting material in Europe. This thesis is based on the hypothesis, that an improved implementation of the organic regulation 2018/848 and the introduction of national provisions and incentives could potentially support a “level playing field” in the organic seed sector by ensuring that all players in the market adhere to the same standards for organic production and labelling. This could lead to increased trust in organic seeds among producers and may foster investments in the organic seed and breeding sector. An inventory by Solfanelli et al. (Solfanelli et al., 2021) indicated national seed provision on category I lists of certain crops and sub-crops with sufficient supply of organic seed in Belgium, France, Germany, Luxembourg, the Netherlands, Sweden, and Switzerland. Until today, EU Member State authorities have implemented policy measures, such as public subsidies on the production and use of organic seed provisions such as pre-ordering periods, sub-groups of crops for which no derogations can't be granted any more. With implementing national measures, the supply of organic seed has been steadily developing (Solfanelli, Ozturk, Dudinskaya, et al., 2022). However, there are still many crops and sub-groups of crops for which not sufficient or only very few organic seed and planting material is available from organic multiplication (Solfanelli, Ozturk, Dudinskaya, et al., 2022).

The aim of this thesis is to analyse the perspectives of stakeholders in the organic seed and breeding sector and identify the barriers that prevent them from becoming more active in this field. It will examine key criteria that can support the development of the organic seed and breeding sector within the European Union. Additionally, this work will contribute to the broader question of whether it is feasible to phase out the use of non-organic seeds and planting materials in the European Union by the end of 2036.

## **1.5 Outline & Research Questions**

This thesis was carried out within the framework of, and funded through, the research and innovation project “LIVESEED” ([www.liveseed.eu](http://www.liveseed.eu)). Data collection of this thesis was carried out within activities conducted within work package 1.

The three main research questions summarize the objective:

1. What barriers exist to expand organic seed and breeding activities from seed suppliers and breeders' perspective?
  - To identify barriers that hinder actors to expand their activities in the organic seed and breeding sector (research question 1, Figure 7), results of an online survey with 210 completed responses conducted within LIVESEED WP1 were analysed. For this a principal factor analysis (PFA) method was applied to identify latent factors that explain the interrelationships between observed variables and to uncover underlying constructs (Costello & Osborne, 2005; Skerman et al., 2009; Wang, 2009). Like principal component analysis (PCA), PFA reduces data dimensionality by summarizing the information contained in a large set of variables into a smaller set of factors, which simplifies data interpretation and analysis. PFA can be applied to various types of data, including those with Likert-type scales, which are prevalent in social science surveys (Schreiber, 2021).
2. Can the implementation of national seed provisions and policy measures promote supply and uptake of organic seed and planting material?
  - To analyse if the implementation of national measures can support supply and uptake of organic seeds and planting material (research question 2, Figure 7), a statistical analysis of data obtained from the national organic seed database in Germany was conducted within LIVESEED WP1.
3. Are there overarching criteria that improve governance of the organic seed and breeding sector in context of the organic farming regulation 2018/848?
  - To test overarching criteria that improve governance of the organic regulation 2018/848 (research question 3, Figure 7) work carried out in LIVESEED WP1 was considered.

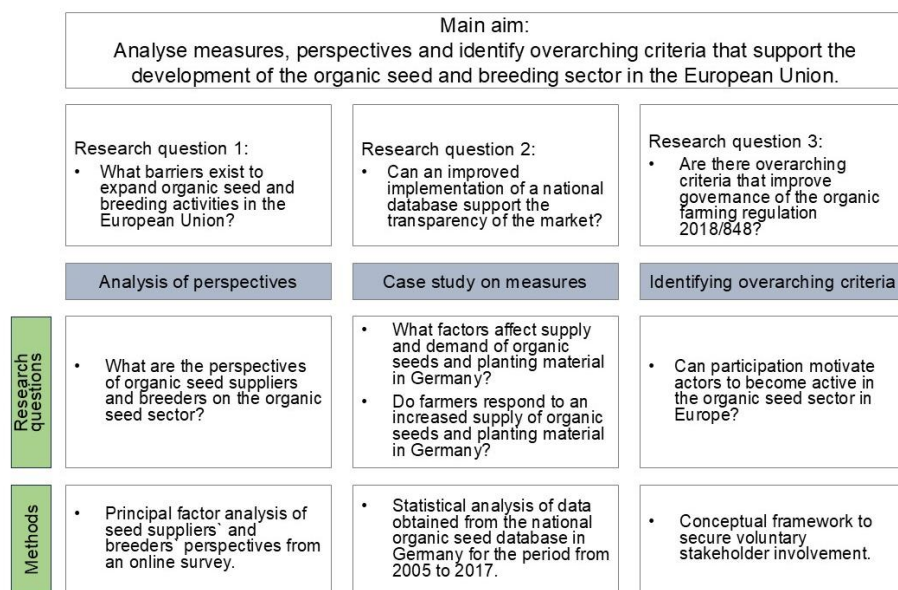


Figure 7. Outline highlighting research questions and methods and how they feed into this dissertation's main research questions and aims.

## **2. Breeding and Multiplying Cultivars for the Organic Farming Sector in Europe – An Explorative Factor Analysis on Seed Suppliers` and Breeders Perspectives**

This chapter is based on the paper:

Freya Schäfer, Xenia Gatzert, Francesco Solfanelli, Raffaele Zanolli, Eva Winter, Susanne Padel, Maaïke Raaijmakers, Monika Messmer. “Breeding and Multiplying Cultivars for the Organic Farming Sector in Europe – An Explorative Factor Analysis on Seed Suppliers` and Breeders Perspectives”.

This paper will be submitted to the EUCARPIA Scientific Conference on “Breeding to meet environmental and societal challenges” at Instituto Politécnico de Coimbra – ESAC, Coimbra, Portugal from 26th to 28th May 2025.

### **Abstract**

To foster the transition towards sustainable food systems the European Union targeted in the Green Deal and Farm-to-Fork strategy to increase the organic area from 10 to 25% by 2030. To achieve this goal the production of organic seed and planting material of cultivars suited for organic production must be increased dramatically. Therefore, it is important to understand the seed market dynamics and bottlenecks in Europe. This study focused on breeders’ and seed suppliers’ perspectives towards the market opportunities and challenges of organic seed and planting material of cultivars especially suited for the European organic farming sector. In addition to agronomic factors also socio-economic and ethical aspects were considered. Through a principal factor analysis, two set of statements were examined for possible factors underlining perspectives of responding supplier and breeder on the organic seed and breeding market in Europe. The analysis revealed the following five most influential factors with respect to organic seed production: A-I demanding more information and support to perform organic seed production; A-II technical and marketing aspects; A-III regulatory barriers in organic seed production; A-IV trust in the development of the organic seed market; A-V seed health and technical production aspects. With respect to breeding for the organic farming sector the following five factors were identified: B-I strong focus on organic and participatory breeding for diversity; B-II encountering knowledge gaps to breed under organic conditions; B-III breeding for traits needed in organic farming; B-IV targeting conventional breeding goals; B-V encountering financial barrier to conduct breeding under organic conditions. The results indicate that there are clear distinctive stakeholders’ perspectives that separate individual views on the organic seed and breeding sector in Europe. Larger companies who start organic seed production may encounter organisational difficulties in scaling-up organic seed

production, finding farmers willing to multiply under organic conditions or face seed health and seed treatment constraints, while smaller companies retrieve a need to receive more training, financial support and an improved organic seed market transparency. Breeding companies and initiatives who fully conduct all their breeding under organic conditions are associated with a very small companies' turnover. Thus, mainly very small companies perform organic breeding who often lack a financial basis to further expand breeding activities. Larger companies focus on breeding for the organic farming sector, but don't conduct all breeding steps under organic conditions.

### **Keywords**

Organic seed market, plant breeding, principal factor analysis, seed business, organic seed production, plant reproductive material

## **2.1 Introduction**

The European organic farming sector is a steadily growing market with more farmers converting to organic farming practises (Willer et al., 2024). In 2022, 16.9 million ha accounting for 10.4 % of the farming area were under certified organic cultivation in the European Union (Willer et al., 2024). To mitigate towards more sustainable farming practises, the European Commission aims to increase the organic farming area up to 25% in the EU by 2030 (European Commission, 2020). The annual growth rate of organic farming has been around 6% from 2012 to 2021. To achieve the 2030 target, this rate needs to increase to approximately 10.1% annually (Eurostat, 2024). However, the demand for organic products has become unstable since 2022, impacting the growth of the organic sector. Market support is crucial as sales have declined since 2021 (Eurostat, 2024). With the anticipated increase in organic farming area, the demand on organic seed of cultivars suited for organic production is also increasing. The first comprehensive organic seed market study in 2018 revealed a considerable lack of organic seed supply in the European market (Solfanelli, Ozturk, Dudinskaya, et al., 2022) as well as a lack of suitable cultivars for organic farming (Orsini et al., 2020; Solfanelli, Ozturk, Dudinskaya, et al., 2022).

There are contradicting statements towards the need to breed for organic agriculture and if separate organic breeding programs are justified (Carvallo Lopez et al., 2024; Crespo-Herrera & Ortiz, 2015; Lammerts Van Bueren et al., 2011; Murphy et al., 2007; Sandro et al., 2022). While this debate is based on limited experimental data, there are also differing perspectives on the suitability of conventionally bred varieties for organic farming systems which is reinforced by the present political debate on deregulating new genomic techniques in Europe (Mandolesi et al., 2022; Nuijten et al., 2017; Puchta, 2024). This highlights the complex balance between adhering to organic principles, meeting specific organic farming needs, and practical considerations of resources and market size. As

organic farming continues to grow, justification for separate breeding programs may become stronger. Within the framework of the EU Horizon 2020 three projects were funded to boost the organic seed and plant breeding sector. LIVESEED (LIVESEED, 2017) aimed at harmonizing the implementation of EU regulations related to organic seeds, improving transparency and functionality of organic seed databases across member states and promote novel breeding methods tailored to organic farming, including system-based breeding concepts that integrate broader sustainable development goals (Lammerts Van Bueren et al., 2018). Following a multi-stakeholder approach relevant actors along the organic seed and breeding supply chain were involved in LIVESEED ([www.liveseed.eu](http://www.liveseed.eu)) covering agricultural, vegetables, forage and fruit crops. The project ECOBREED ([www.ecobreed.eu](http://www.ecobreed.eu)) focussed on wheat, soybean, potato and buckwheat, while BRESOV ([www.bresov.eu](http://www.bresov.eu)) concentrated on brassica vegetables, tomato and green beans.

### **Regulatory framework and market failure of organic seed and planting material for the European organic sector**

The organic Regulation 2018/848 state that the organic farmers are obliged to use organically multiplied plant reproductive material if available (European Union, 2018). However, Döring et al. (Döring et al., 2012) analysed, that due to low investments in the past or other market-related reasons organic seed and vegetative propagating material is often not available in a sufficient quantity. Thus, a high number of derogations on the use of non-organic seeds has been reported by European Member States year by year. Orsini et al. (Orsini et al., 2020) analysed factors affecting farmers to use organic seed and showed that the situation of organic seed use differs across geographical regions and crop sectors. In Central European regions, covered by the countries Austria, Belgium, France, Germany, Luxembourg, the Netherlands, and Switzerland, the organic seed use seems to be higher than in other geographical regions in Europe. This result is confirmed by Schäfer et al. (Schäfer et al., 2024) and Solfanelli et al. (Solfanelli, Ozturk, Dudinskaya, et al., 2022) who analysed in detail supply and demand of organic seed in Europe. The share of non-organic seed use granted through derogation varied between 48.5% in Eastern EU regions, 38.1% in Southern EU regions, 33.0% in Northern EU regions and 18.6% in Central EU regions (Solfanelli, et al., 2022). The percentage of non-organic seed use decreased from fruit production (41.9%), followed by forages (35.6%), arable crops (29.8), and vegetables (24.6%) (Solfanelli, Ozturk, Dudinskaya, et al., 2022). Beside the need to increase organic seed production, the research of Orsini et al. (Orsini et al., 2020) showed that the availability of cultivars, suitable for organic production, play an important part on farmers choice of seed. Thus, farmers state to prefer suitable cultivars, rather than an unsuitable cultivar multiplied under organic conditions (Orsini et al., 2020). Seed Production under certified organic conditions requires adhering to a specific set of certifications and regulations, which can be both challenging and expensive to fulfil

(Raaijmakers & Schäfer, 2019). These hurdles can make it less appealing for seed companies to invest in organic seed production and breeding activities. Additionally, low demand for organic seeds and the frequent use of derogations for non-organic seeds can deter investments, as seed producers may struggle to cover their production costs (Raaijmakers & Schäfer, 2019). On the other hand, the demand for organic seed of suitable cultivars is growing, driven by increasing consumer demand for organic food and a growing awareness of the environmental and health benefits of organic farming (Horrihan et al., 2002; Martini et al., 2024; Valero-Gil et al., 2023) and by the regulation targets to phase out the use of non-organic seed and planting material latest by end of 2036 (European Union, 2018). Meanwhile, the limited availability of organic seed of small number of cultivars can make it difficult for farmers to switch to organic multiplied seed and vice versa for seed companies to invest in organic seed production if derogations are widely applied (Raaijmakers & Schäfer, 2019). This can create a supply-demand paradox, where seed suppliers may question if it is worth starting organic seed production if there is little demand (BFICSS, 2014). Furthermore, there have been concerns raised about transparency and a lack of level playing field in the organic seed market across Europe. Limited capacity for breeding locally adapted cultivars suited for organic farming conditions further complicates the situation.

### **Breeding for the European organic farming sector**

While there is a mandatory regulation to use organic seed and planting material multiplied under certified organic conditions, there is no such obligation for the choice of cultivars. However, in the present organic Regulation 2018/848 there is for the first time a legal definition for “organic varieties suited for organic production” and for “organic heterogenous material”, both developed under certified organic conditions (European Union, 2018). It is estimated that more than 95% of organic agriculture is based on crop varieties that were bred for the conventional high-input sector with selection in conventional breeding programmes (Lammerts Van Bueren et al., 2011). Lammerts van Bueren et al. (Lammerts Van Bueren et al., 2018) conclude that some breeding goals are the same for conventional and organic agriculture, such as yield increase, climate change adaptation, or baking quality. In organic agriculture, certain breeding objectives take precedence, such as developing crops with enhanced resilience and adaptability, fostering positive interactions between plants and soil microorganisms and improving resistance to diseases. However, these goals sometimes conflict with those pursued in conventional agriculture breeding programs. This divergence highlights the distinct priorities and approaches between organic and conventional farming systems in crop development (Lammerts Van Bueren et al., 2018). A prime example of conflicting breeding goals is the development of semi-dwarf wheat varieties. The breeding purpose was to increase yields in intensive farming systems. Which

resulted in new cultivars with shorter stalks, which led to a reduced ability to compete with and suppress weeds and a decreased efficiency in nutrient uptake. This case illustrates how breeding strategies optimized for high-input conventional agriculture may produce traits that are less desirable or even disadvantageous in organic farming systems (Lammerts Van Bueren et al., 2011). Hoad et al. (Hoad et al., 2006) state that in selecting cereal varieties suited to organic farming high crop ground cover is the most important feature for creating a highly competitive crop that also has consistency in yield. Crespo-Herrera & Ortiz (Crespo-Herrera & Ortiz, 2015) argue that conventional breeding programs aiming for similar breeding goals like high productivity, host plant resistance or tolerance to biotic and abiotic factors, and high resource-use efficiency and thus conventional breeding programs also serve the needs of organic agriculture. However, they also stated that conventional plant breeding cannot always provide suitable cultivars for organic farming in various crops such as cereals and pulses and acknowledged achievements of dedicated organic breeding programs (Crespo-Herrera & Ortiz, 2015). Post-registration variety trials under organic conditions are required to select those varieties that can thrive under organic management practices, which often differ significantly from conventional farming methods. Miko et al. (Mikó et al., 2014) found seven out of the 15 traits assessed in wheat significant management x genotype interaction. Therefore, they recommended for economic reasons, selecting more heritable traits in conventional fields while selection for grain yield and early vigor during booting should be done under organic conditions. This is confirmed by Baenziger et al. (Baenziger et al., 2011) and Kirk et al. (Kirk et al., 2012) who found higher wheat yield under organic management if selection was conducted under this management system. This suggests that combining data from both systems can be beneficial for making selection decisions. However, relying solely on non-organic trial data for organic farming decisions is not suitable, as the ranking agreement between the two systems is only moderate (Przystalski et al., 2008). Murphy et al. (Murphy et al., 2007) and Reid et al. (Reid et al., 2009) argue that it is necessary to carry out selection solely under organic environments as it is the only way for the plants to fully express their genetic potential. This perspective is rooted in the idea that the unique conditions of organic environments are essential for the accurate assessment of a plant's ecological performance and reproductive success. Beside agronomical requirements such as weed suppression, resistance to seed and soil-borne diseases and nutrient use efficiency there are also social and ethical aspects to be considered in developing suitable cultivars for organic farming (Lammerts Van Bueren et al., 2018) as well as the applied techniques in the breeding process (Nuijten et al., 2017). The organic Regulation 2018/848, Art. 5 state that the use of GMOs is prohibited in organic agriculture (European Union, 2018). The European Consortium of Organic Plant Breeding

([www.ECO-PB.org](http://www.ECO-PB.org)) defines organic breeding as a process of developing new crop varieties that are well-suited for organic farming systems (ECO-PB, 2012). Organic breeding is also focused on preserving genetic diversity and the use of open-pollinated cultivars, landrace varieties and heterogeneous materials, also known as populations, rather than hybrids and the use of genetically modified varieties is prohibited. Organic breeding differs from conventional breeding in several ways, primarily due to the distinct requirements and constraints of organic farming systems. The approach is based on the use of traditional plant breeding methods respecting ethical considerations that the cell is respected as an indivisible entity and technical/physical invasion below the cell level is refrained from (e.g. through transmission of isolated DNA, RNA, or proteins, or through artificial mutagenesis, cell fusion) and the ability of a variety to reproduce in species-specific manner has to be maintained and technologies that restrict the germination capacity of seed-propagated crops are refrained from (ECO-PB, 2012). The exchange of genetic resources is encouraged and any patenting of living organisms, their metabolites, gene sequences or breeding processes are refrained from. The applied breeding techniques will be disclosed to enable producers and consumers to choose varieties according to their values (e.g. clear declaration of varieties derived from mutation breeding). Participatory breeding programmes involving all stakeholders (producers, processors, retailers and consumers) are promoted. Involving farmers directly in the selection process through participatory plant breeding (PPB) can produce cultivars better suited to organic farming conditions. This approach has shown success in developing wheat varieties with better yield and baking quality (Grovermann et al., 2022) better yields and weed suppression capabilities (Entz et al., 2015). In conclusion, a plurality of independent breeding programs and breeders with different types of crops to increase agricultural biodiversity is aspired. The use of locally adapted varieties, wild relatives, and landraces, and the conservation of genetic resources are prioritized (ECO-PB, 2012). Breeding programs specifically targeting low-input organic conditions have shown some promising results. For example, varieties of squash, cucumber, lettuce, and yardlong bean developed under organic conditions demonstrated significant yield advantages and pest resistance (Maghirang et al., 2017).

Following ECO-PBs definition (ECO-PB, 2012) of Organic Plant Breeding (OPB) distinguish three approaches of plant breeding:

1. Organic Plant Breeding (OPB):
  - All steps (crossing, selection, multiplication) are conducted under certified organic conditions.
  - Fully aligned with organic principles and regulations.
2. Breeding for Organic (BFO):
  - Some steps (crossing, early selection) are conducted under conventional conditions.
  - Specific breeding goals for organic are considered, no genetic engineering or cell fusion applied
  - Later generations are tested and multiplied under organic conditions.
  - Hybrid approach combining conventional and organic methods.
3. Conventional Breeding (CB):
  - Focused on mainstream conventional agriculture.
  - Selection occurs entirely in conventional breeding programs and conventional sites.
  - Not specifically tailored for organic farming systems.

These definitions highlight a spectrum of breeding approaches, from fully organic (OPB) to conventional (CB), with BFO as an intermediate strategy. The distinctions are important for understanding how varieties are developed and to what extent they have been tested for suitability for organic farming systems (ECO-PB, 2012).

While Orsini et al. (Orsini et al., 2020) analysed the factors affecting the use of organic seed by farmers, this study here examined the viewpoints of breeders and organic seed producers regarding the breeding and seed production of cultivars specifically suited for organic farming. Main objectives are (i) identifying if there are distinguishing perspectives between actors (ii) analysing if there are correlations between the region where organisations are located (iii) monetary factors, such as yearly turnover from seed sales (conventional & organic) or relevance of the organic seed and breeding business is related to relevant factors underlining perspectives of actors. The research employs principal axis factor analysis to investigate two sets of statements, aiming to uncover underlying factors that shape stakeholders' attitudes towards the European organic seed and breeding market.

## 2.2 Materials and Methods

An online survey was developed in consultation with stakeholders of the European seed and breeding supply chain, including seed associations, researcher, and breeding initiatives in the scope of the LIVESEED project. The survey was pre-tested on 18 seed companies and breeding initiatives in Germany and Italy and optimized in an iterative approach among LIVESEED partners and seed experts. The survey was conducted during the period from October 2018 till January 2019. To identify perspectives of actors towards organic seed production and breeding for the organic farming sector, different views were identified by the authors from the literature on organic seed production and breeding for the organic farming sector in accordance with the purpose of the subject. The statements were formulated by scanning and examining the literature. In the reviewed literature (Crespo-Herrera & Ortiz, 2015; Döring et al., 2012; Fleck, 2016; Groot et al., 2004; Lammerts van Beuren et al., 2003; Lammerts Van Bueren et al., 2018; Osman et al., 2008; Rey et al., 2014; Willer & Schmid, 2016) the most important statements were selected. In addition, the authors also consulted project partners to refine and define the statements. Related to organic seed production a set of 22 statements and related to breeding for the organic farming sector a set of 23 statements were selected. Statements were presented to the respondents included in the survey conducted and the level of accepting each statement were measured using a 5-point Likert scale (1: fully disagree, 2: somewhat disagree, 3: indifferent, 4: somewhat agree, 5: fully agree). No sensitive personal data were collected, and all data were anonymized. The survey was administered with the support of LIVESEED partners (involving translations and dissemination) and directly distributed to a total of 743 organic and conventional seed and breeding companies using the software Qualtrics.com. The addresses were collected from the networks of partners involved in the LIVESEED project. In addition to the individual survey requests, the European seed association [www.Euroseeds.eu](http://www.Euroseeds.eu) (with 34 national member associations from EU Members States and beyond, represents several thousand seed businesses, as well 67 direct company members, including from seed related industries) and the European Consortium of Organic Plant Breeding (ECO-PB) (with 14 organizational and 29 individual members) forwarded the link of survey to their members in order to reach out to all actors of the European seed sector. The survey was also forwarded to the LIVESEED project stakeholder platform, to all project partners, published at the [Liveseed.eu](http://Liveseed.eu) website and posted on social media and it was available in the languages English, French, German, Hungarian, Italian, and Spanish. The survey received 301 responses, with 210 (69.77 percent) completed responses that could be included in the analysis. Out of 210 responses, only 41 (19.52 %) respondents do not trade organic seed (conventional seed trade only), leading to an over-representation and good coverage of 169 actors dealing with organic seed who responded to the survey. 26 respondents handle exclusively organic seed, and 143 respondents handle both organic and conventional seed. Out

of the 210 completed responses, 197 were recorded from 26 EU Member States including the United Kingdom, and 13 responses from countries outside the European Union (Switzerland, Serbia, Tunisia, and Moldova). Similarly, to Solfanelli et al. (Solfanelli, Ozturk, Dudinskaya, et al., 2022) and Orsini et al. (Orsini et al., 2020), for further analysis countries were grouped into the following five regions: Northern EU, Eastern EU, Central EU, and Southern EU and “outside-EU”. Switzerland was grouped with the Central region of Europe (Central EU) because Swiss organic production certification was in line with the European Council regulation (EC) 834/2007 on organic production and its implementing regulation (EC) 889/2008. Table 2 displays the regions with countries and the number of responses to the survey per country.

Table 2: Responses to the survey per country, grouping to regions within and outside the European Union

Country (number of responses per country)	Region	Sum of responses per region
Austria (7), Belgium (2), France (22), Germany (51), Luxembourg (2), Netherlands (25), Switzerland (8)	Central countries of the EU & Switzerland	117
Croatia (2), Cyprus (1), Greece (3), Italy (26), Matla (0), Portugal (2), Slovenia (2), Spain (6)	Southern countries of the EU	42
Denmark (4), Estonia (1), Finland (4), Ireland (4), Latvia (7), Lithuania (2), Sweden (2), United Kingdom (6)	Northern countries of the EU	30
Bulgaria (8), Czech Republic (2), Hungary (1), Poland (2), Romania (3), Slovakia (0)	Eastern countries of the EU	16
Serbia (3), Tunisia (1), Moldova (1)	Countries outside of the EU	5
	Total	210

Based on the grouping of countries, the survey received 117 responses from Central EU countries (incl. Switzerland), 42 responses from Southern EU countries, 30 responses from Northern EU countries, 16 responses from Eastern EU countries, and 5 responses from “outside EU countries”. With 117 out of 210 responses (almost 56%) the survey resulted in an overrepresentation of responses from Central EU countries. Germany was the most represented country with 51 responses (24.3 %), followed by Italy with 26 responses (12.4 %), the Netherlands with 25 responses (11.9 %) and by France with 22 responses (10.5 %) (Figure 8). From Malta and Slovakia no response was retrieved. To analyse the perspectives of actors towards organic seed production and breeding for the organic farming sector three further relevant questions were selected to test identified factors.

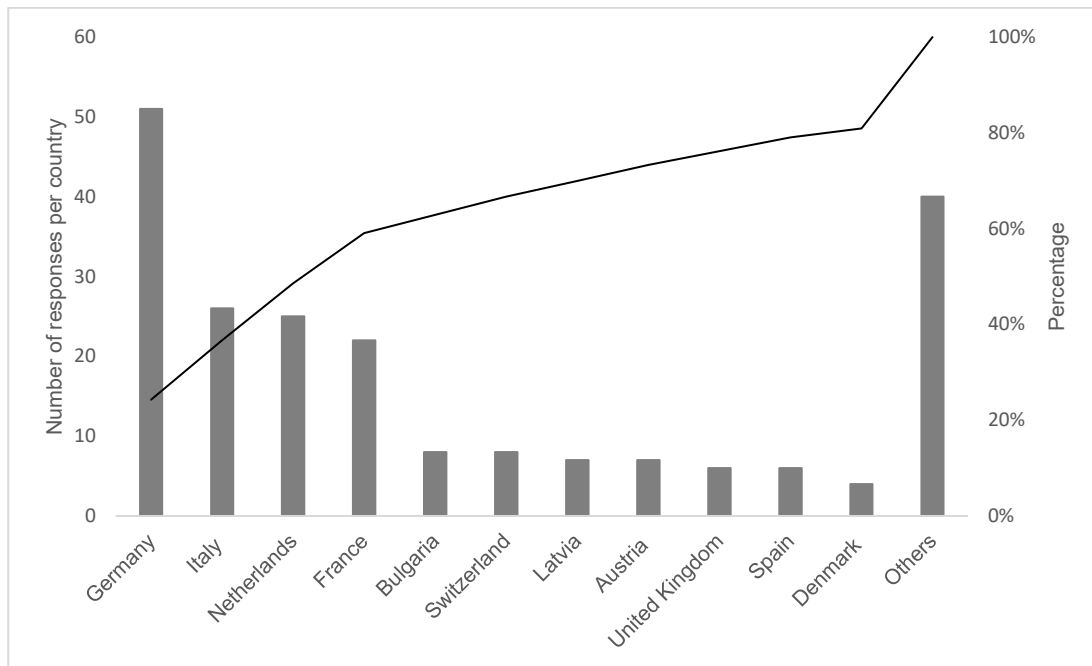


Figure 8 Pareto-chart ordered by number of responses per country, individual values are represented in descending order by bars, and the cumulative total is represented by the line.

The following three questions were selected for further analysis: (i) region where company is located, (ii) companies' turnover per year, and (iii) turnover from organic seed and breeding sales activities in percent (0-100). Table 3 illustrates the steps conducted in this research. According to the suggestion of Costello and Osborne (Costello & Osborne, 2005), a principal factor analysis (PFA) was chosen due to the non-normally distributed data. PFA is a robust method for factor analysis that does not require multivariate normality (Skerman et al., 2009). Statistical analysis was performed with statistical software SPSS version 29.0 (SPSS, 2024). The data collected in the present study were analysed via factor analysis and Spearman rank correlations. Factor analysis is a frequently used multivariate statistical analysis method that transforms a large number of related variables into a smaller number of independent factors (Yong & Pearce, 2013). PAF focuses on identifying the underlying factor structure within a dataset by analysing the shared variance among variables, excluding unique variance (SPSS, 2024) and explains the reason for the mutual dependence among the variables in the dataset by reducing them to a smaller number of variables. To test if the data is suited for factor analysis a Barlett's Test of Sphericity and Kaiser-Meyer-Olkin (KMO) test were conducted to both sets of statements. The greater the correlation values of a Barlett's Test are among the variables the higher the probability that the variables will form common factors (Yong & Pearce, 2013). Kaiser-Meyer-Olkin (KMO) test measures sampling adequacy by comparing the magnitude of the observed correlation coefficients. The KMO criterion should be greater than 0.5. Higher KMO values indicate higher suitability of the dataset for factor analysis (Hair, 2023). The eigenvalue scree test

and variance criteria are important criteria taken into consideration when deciding on the number of factors. The eigenvalue indicates the total variance explained by each factor. To determine the number of factors to retain in the multi-item scale, a visual scree plot method was used. Factors above the distinct breakpoint in the slope, known as the elbow point, were retained (Raïche et al., 2013). Only factors with the eigenvalues of above 1.0 were selected during the implementation. Varimax rotation was applied to maximize the factor variances after which principal components method was used for factor analysis for a better interpretation of the results.

Table 3 Data collection and data analysis including applied methods.

Steps conducted		Applied method
1. Identification of 22 statements on organic seed production	2. Identification of 23 statements on breeding for the organic farming sector	Literature review of peer-reviewed and grey literature
3. Developing a questionnaire, pre-testing the survey and running the online survey from October 2018 till January 2019 with 210 completed responses		Online survey via Qualtrics.com
4. Analysing responses of the survey on relevant factors that underline attitudes of actors towards organic seed production and breeding for the organic farming sector		Principal factor analysis via SPSS 29.0
5. Analysing if there are correlations between the region where organisations are located, if monetary factors, such as yearly turnover from seed sales (conventional & organic), relevance of the organic seed and breeding business are related to relevant factors underlining perspectives of actors derived from the principal factor analysis		Correlation matrix (Spearman rank correlations)

## 2.3 Results

From the literature review identified statements on organic seed production and breeding for the organic farming sector were split into two sets.

Table 4 lists the 22 statements on organic seed production (Code A1 to A22) including descriptive statistics (including mean, standard deviation, and Cronbach's alpha if item was deleted). Table 5 lists the 23 statements on breeding for the organic farming sector (Codes B1-B23) including descriptive statistics (including mean, standard deviation, and Cronbach's alpha if item was deleted). The total number of valid responses for both sets of items was n=210.

Table 4: Codes, descriptive statistics, and Cronbach's alpha if item deleted on 22 statements on organic seed production

Codes	Statements on organic seed production	No.	Mean	Standard deviation	Cronbach's alpha
A01	Phasing out of derogations for conventional seed in the new organic regulation	210	3.75	1.285	0.717
A02	Stricter national standards in allowing derogation for conventional seed in the next 5 years	210	3.70	1.349	0.712
A03	Availability of a larger range of organically allowed seed treatments	210	3.60	1.231	0.722
A04	Introduction of (e.g. governmental) subsidies to support organic seed production	210	3.40	1.415	0.706
A05	More information on organic seed demand of EU and non-EU-markets	210	3.73	1.164	0.706
A06	More training offers on organic seed production	210	3.48	1.191	0.701
A07	More research into making organic seed production more profitable	210	3.81	1.165	0.704
A08	Organic seed production is technically more challenging in comparison to conventional seed production in terms of yield losses/volatility	210	4.10	1.082	0.713
A09	Organic seed production is technically more challenging in comparison to conventional seed production in terms of hybrid production	210	3.15	1.147	0.713
A10	Organic seed production is technically more challenging in comparison to conventional seed production in terms of storage and treatment	210	3.63	1.180	0.718
A11	Organic seed production is technically more challenging in comparison to conventional seed production in terms of seed-borne pests and diseases	210	4.05	1.039	0.721
A12	Organic seed production is technically more challenging in comparison to conventional seed production in terms of weed contamination	210	3.85	1.101	0.719
A13	Organic seed production is technically more challenging in comparison to conventional seed production in terms of finding enough farmers willing to multiply organic seed	210	3.71	1.176	0.710
A14	Organic seed production is technically more challenging in comparison to conventional seed production in terms of germination rate and seed size	210	3.31	1.200	0.717
A15	Organic seed production is technically more challenging in comparison to conventional seed production in terms of contamination with GMO	210	2.71	1.303	0.716
A16	Organic seed production is currently a profitable niche market	210	3.19	1.150	0.729
A17	Organic seed production is a growing market that might become profitable in the next 5 years	210	3.65	0.938	0.713
A18	Offering both organically and conventionally produced seed is logistically too costly	210	2.78	1.231	0.721
A19	Organic seed production is more costly than conventional seed production	210	4.39	0.973	0.710
A20	Organic seed is an important part of organic agriculture	210	4.22	1.145	0.711
A21	Demand for organic seed is more volatile than demand for conventional seed	210	3.50	1.146	0.724
A22	Farmers are willing to pay the higher price for organic seed	210	3.14	1.247	0.731

The statements were prepared in the form of a 5-point Likert scale with the responses of: 1: fully disagree, 2: somewhat disagree, 3: indifferent, 4: somewhat agree, 5: fully agree.

Table 5: Codes, descriptive statistics, and Cronbach's alpha if item deleted on 23 statements on breeding for the organic farming sector

Codes	Statements on breeding for the organic farming sector	No.	Mean	Standard deviation	Cronbach's alpha
B01	Protecting our crop germplasm/maintaining plant genetic resources	210	4.09	0.965	0.768
B02	Breeding neglected crops to improve agro biodiversity	210	3.21	1.274	0.756
B03	Developing open pollinated cultivars as alternatives to F1 hybrid seed	210	2.75	1.410	0.751
B04	Selecting for local adaptation	210	3.80	1.200	0.757
B05	Involving farmers in the breeding process	210	3.22	1.309	0.755
B06	Collaborating closely with the organic value chain to select best cultivars	210	3.96	1.055	0.759
B07	Breeding for diversity (e.g. composite crosses population breeding for mixed cropping)	210	3.25	1.304	0.754
B08	Carrying out all steps from crossing selection and maintenance under organic conditions	210	3.04	1.460	0.749
B09	Breeding cultivars that are fully suited for organic growing conditions	210	4.02	1.119	0.759
B10	Breeding cultivars with good taste	210	4.04	1.082	0.767
B11	Breeding cultivars with high nutritional quality	210	3.97	1.051	0.761
B12	Meeting the demand of organic production	210	4.13	0.979	0.760
B13	There is a lack of knowledge in our company on the management of organic breeding field trials	210	2.58	1.205	0.768
B14	There is a lack of knowledge in our company of organic agriculture breeding goals/criteria	210	2.47	1.183	0.761
B15	There is a lack of knowledge in our company of potential organic markets	210	2.75	1.326	0.760
B16	There is a lack of adapted rules to register varieties suitable for organic growing conditions	210	3.08	1.223	0.754
B17	There is a lack of knowledge in our company on financing models of dedicated organic breeding programmes	210	3.05	1.254	0.761
B18	Low return on investment of dedicated organic breeding programmes prevents our company from breeding organic cultivars	210	3.26	1.199	0.774
B19	We do not have an organic breeding programme because we cannot use all available breeding techniques in organic breeding	210	2.68	1.253	0.773
B20	The organic market is too small to justify separate breeding	210	3.24	1.331	0.792
B21	Organic breeding is key for improving the performance of organic agriculture	210	3.45	1.355	0.755
B22	The best cultivars for conventional farming are also the best cultivars for organic farming	210	2.68	1.271	0.790
B23	It is sufficient to test conventionally bred cultivars for their suitability under organic growing conditions	210	3.16	1.254	0.793

The statements were prepared in the form of a 5-point Likert scale with the responses of: 1: fully disagree, 2: somewhat disagree, 3: indifferent, 4: somewhat agree, 5: fully agree

The Kolmogorov-Smirnov revealed for all 45 Likert-scale items a p-value of < 0.001. For both sets of statements the sampling adequacy was examined by KMO and a Bartlett's Test of Sphericity (Table 6). The analysis reveals that the 22 selected statements towards organic seed production (codes A01-A22) show a KMO

sampling adequacy of 0.669 and the 23 selected statements on breeding for the organic farming sector (codes B01-B23) a KMO sampling adequacy of 0.0857 (Table 6). According to Hair (Hair, 2023) the KMO values of both sets of statements can be evaluated as 'moderate' to evaluate attitudes on organic seed production and as 'very good' to evaluate attitudes on breeding for the organic farming sector.

Table 6 Kaiser-Meyer-Olkin and Bartlett's Test on codes A1-A22 and codes B1-B23 items

		Codes A1-A22	Codes B1-B23
Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		0.669	0.857
Bartlett's Test of Sphericity	Approx. Chi-Square	958.076	1742.917
	Degree of freedom	231	253
	Probability of error	<.001	<.001

### Exploratory factor analysis

For statements towards organic seed production (codes A1-A22), the principal axis factor analysis revealed initially 7 factors explaining 40.7% of the variance. However, factor 6 and 7 only showed high factor loadings on one statement each. Thus, the number of factors was reduced to 5, which could explain 34.5% of the variance (Table 6, Figure 2). For statements towards breeding for the organic farming sector (codes B1-B23), the analysis identified 5 factors explaining 47.8% of the variance (Table 7, Figure 9). The oblique rotation method 'varimax' with Kaiser Normalization was applied to both sets of statements.

Table 7 Initial Eigenvalues and variance on statement towards organic seed production (codes A1-A22)

Factor	Initial Eigenvalues			Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadings	
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %	Total	% of Variance
1	3.508	15.947	15.947	2.894	13.155	13.155	1.953	8.878
2	2.611	11.868	27.815	1.981	9.005	22.160	1.658	7.538
3	1.665	7.566	35.381	1.069	4.859	27.019	1.453	6.607
4	1.510	6.863	42.244	0.986	4.482	31.501	1.362	6.190
5	1.335	6.068	48.312	0.667	3.034	34.535	1.171	5.322

Extraction Method: Principal Axis Factoring.

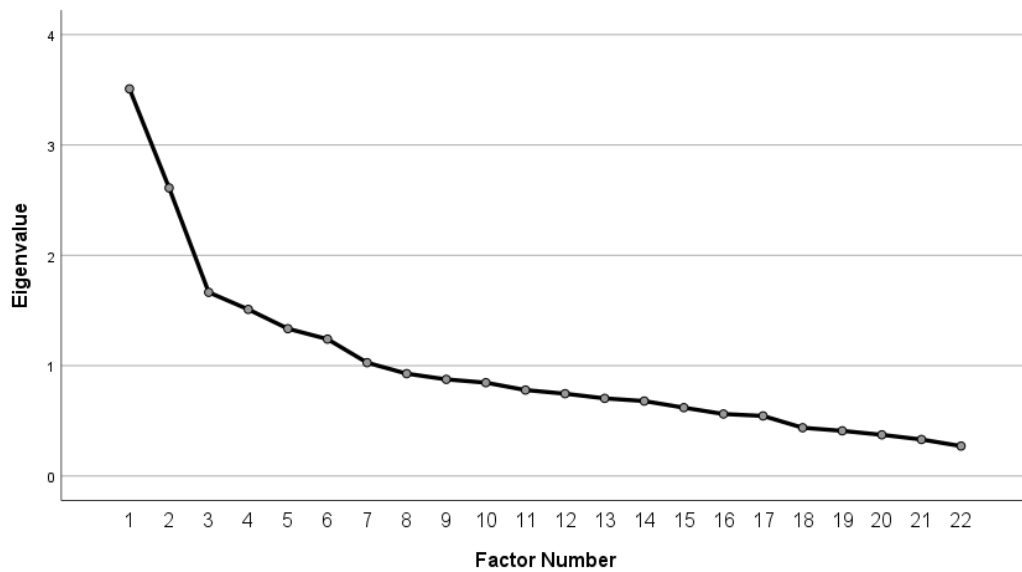


Figure 9 Scree Plot with Eigenvalues of factor number 1 to 22 on statements towards organic seed production.

Table 8 Initial Eigenvalues and variance on statement towards breeding for the organic farming sector (codes B1-B23)

Factor	Initial Eigenvalues			Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadings	
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %	Total	% of Variance
1	5.984	26.019	26.019	5.478	23.818	23.818	3.467	15.072
2	3.217	13.987	40.006	2.722	11.833	35.651	2.547	11.075
3	1.876	8.159	48.164	1.329	5.780	41.431	2.183	9.490
4	1.382	6.008	54.172	0.905	3.935	45.366	2.017	8.771
5	1.042	4.531	58.703	0.560	2.433	47.800	0.780	3.391

Extraction Method: Principal Axis Factoring.

The factor analysis on the first set of Likert-Scale questions focusing on organic seed production revealed five relevant factors (Table 8). The number of statements loading above 0.300 on the different factors varies from seven statements on factor A-I to three statements on factor A-III (Table 8). Only one statement (A20) “organic seed is an important part of organic farming” was loading on two factors (factor A-I and factor A-IV). Table 8 illustrates the five identified factors on organic seed production including statements, codes and factor loadings.

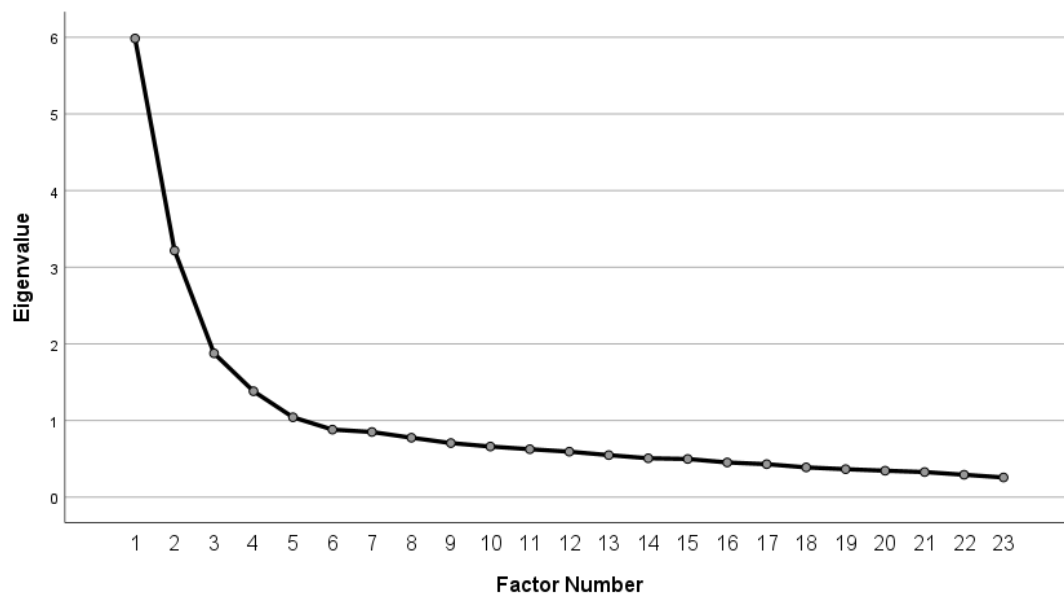


Figure 10 Scree Plot with Eigenvalues of factor number 1 to 22 on statements towards breeding for the organic farming sector

Factor A-I reveals statements on **demanding more information and support to perform organic seed production**. In factor A-I the statement to receive “more training opportunities on organic seed production” and a potential “introduction of (e.g. governmental) subsidies to support organic seed production” show the highest factor loadings of ,703 and ,566 respectively (Table 9).

Factor A-II reveals’ statements focusing on **technical and marketing aspects**. The statements “organic seed production is technically more challenging in comparison to conventional seed production in terms of yield losses/volatility” and “demand for organic seed is more volatile than demand for conventional seed” show the highest factor loadings on factor A-II of ,577 and ,524 respectively (Table 9).

Factor A-III shows high factor loadings on two statements leading to **regulatory aspects**. The statements “stricter national standards in allowing derogation for conventional seed in the next 5 years” and “phasing out of derogations for conventional seed in the new organic regulation” indicate factor loadings of ,834 and ,708 respectively (Table 9). The third statement within factor A-III indicates that actors see “organic seed as an important part of organic farming” (,350).

Factor A-IV indicates that actors seem to have **trust in the organic seed sector to develop**, as the statements “organic seed production is a growing market that might become profitable in the next 5 years”; “organic seed production is currently a profitable niche market”, and “farmers are willing to pay the higher price for organic seed” show high factor loadings (,646 and ,495 and ,477 respectively) (Table 9).

Factor A-V indicates **seed health and technical production aspects** as “organic seed production is technically more challenging in comparison to conventional seed production in terms of seed-borne pests and diseases” and “organic seed production is technically more challenging in comparison to conventional seed production in terms of storage and treatment” show high factor loading of ,579 and ,529 respectively (Table 9).

Table 9: Factors identified through exploratory factor analysis on attitudes towards organic seed production with codes and corresponding statements and factor loadings above 0.300 ordered in descending order for each factor

Factor	Codes	Statement on organic seed production	Factor loading
<b>A-I</b>		<b>Demanding more information and support to perform organic seed production</b>	
	A06	More training offers on organic seed production	0.703
	A04	Introduction of (e.g. governmental) subsidies to support organic seed production	0.566
	A15	Organic seed production is technically more challenging in comparison to conventional seed production in terms of contamination with GMO	0.520
	A07	More research into making organic seed production more profitable	0.468
	A05	More information on organic seed demand of EU and non-EU-markets	0.410
	A20	Organic seed is an important part of organic agriculture	0.350
	A18	Offering both organically and conventionally produced seed is logistically too costly	0.300
<b>A-II</b>		<b>Technical and marketing aspects</b>	
	A08	Organic seed production is technically more challenging in comparison to conventional seed production in terms of yield losses/volatility	0.577
	A21	Demand for organic seed is more volatile than demand for conventional seed	0.524
	A19	Organic seed production is more costly than conventional seed production	0.506
	A14	Organic seed production is technically more challenging in comparison to conventional seed production in terms of germination rate and seed size	0.435
	A13	Organic seed production is technically more challenging in comparison to conventional seed production in terms of finding enough farmers willing to multiply organic seed	0.408
	A03	Availability of a larger range of organically allowed seed treatments	0.325
<b>A-III</b>		<b>Regulatory barriers in organic seed production</b>	
	A02	Stricter national standards in allowing derogation for conventional seed in the next 5 years	0.834
	A01	Phasing out of derogations for conventional seed in the new organic regulation	0.708
	A20	Organic seed is an important part of organic agriculture	0.319
<b>A-IV</b>		<b>Trust in the development of the organic seed market</b>	
	A17	Organic seed production is a growing market that might become profitable in the next 5 years	0.646
	A16	Organic seed production is currently a profitable niche market	0.495
	A22	Farmers are willing to pay the higher price for organic seed	0.477
	A20	Organic seed is an important part of organic agriculture	0.433
<b>A-V</b>		<b>Seed health and technical production aspects</b>	
	A11	Organic seed production is technically more challenging in comparison to conventional seed production in terms of seed-borne pests and diseases	0.579
	A10	Organic seed production is technically more challenging in comparison to conventional seed production in terms of storage and treatment	0.529
	A12	Organic seed production is technically more challenging in comparison to conventional seed production in terms of weed contamination	0.398
	A09	Organic seed production is technically more challenging in comparison to conventional seed production in terms of hybrid production	0.314

The factor analysis on the second set of Likert-Scale questions focusing on breeding for the organic farming sector revealed five relevant factors (**Error! Not a valid bookmark self-reference.**Table 9). The number of statements loading above 0.300 on the different factors varies from ten statements on factor B-I to one statement on factor B-V (**Error! Not a valid bookmark self-reference.**). The statements B11, B16 and B21 load above 0.300 on more than one factor each (**Error! Not a valid bookmark self-reference.**). All other statements indicated factor loadings above 0.300 on one factor only.

Factor B-I indicates statements with **strong focus on organic and participatory breeding for diversity** where breeding is conducted from the perspective of “delivering open pollinated cultivars” (0.715) with a “broad diversity (e.g. composite crosses population breeding for mixed cropping)” (0.682). Where “all steps from crossing selection and maintenance are conducted under organic conditions” (0.673), farmers are involved in the breeding process (0.631), and it is aimed “to select for local adaptation” (0.556). There is a focus to breed “neglected crops to improve agro biodiversity” (0.554) and develop cultivars “with high nutritional quality” (0.488). Thus, respondents rate that “organic breeding is key for improving the performance of organic agriculture” (0.392) and an interest to “breed cultivars with good taste” (0.361). It is claimed that “there is a lack of adapted rules to register varieties suitable for organic growing conditions” (0.341) (Table 10). Given the definition of the European Consortium of Organic Breeding ECO-PB (ECO-PB, 2012), factor B-I draws a strong link to the process oriented organic plant breeding (OPB) as defined by ECO-PB.

Factor B-II indicates **knowledge gaps on organic breeding** that actors are “not familiar with organic breeding goals/criteria” (0.832), “don’t know how to manage organic breeding field trials” (0.679), have a “lack knowledge on potential (organic seed) markets” (0.673), and on “financing models of dedicated organic breeding programmes” (0.585). Furthermore, they “do not have an organic breeding programme because not all available breeding techniques can be used in organic breeding” (0.492) (Table 10**Error! Not a valid bookmark self-reference.**).

Factor B-III indicates statements of breeding for traits needed in organic farming with close connection to the organic sector “aim to meet the demand of organic production” (0.737) by “breeding cultivars that are fully suited for organic growing conditions” (0.660). By “collaborating closely with the organic value chain” (0.596), “cultivars with high nutritional quality” (0.442) are selected. The statement “protecting our crop germplasm/maintaining plant genetic resources” (0.363) could lead to the assumption that official variety registrations and F1 hybrid breeding programmes are conducted to ensure return of investments from breeding activities (Table 10). Taken the ECO-PB definition, factor B-III could be associated with product oriented “breeding for organic farming” (BFO) (ECO-PB, 2012).

Table 10: Factors identified through exploratory factor analysis on attitudes towards breeding for the organic farming sector with codes and corresponding statements and factor loadings above ,300 ordered in descending order for each factor

Factor Codes	Statement on organic seed production	Factor loading
<b>B-I</b>	<b>Strong focus on organic and participatory breeding for diversity</b>	
B03	Developing open pollinated cultivars as alternatives to F1 hybrid seed	0.715
B07	Breeding for diversity (e.g. composite crosses population breeding for mixed cropping)	0.682
B08	Carrying out all steps from crossing selection and maintenance under organic conditions	0.673
B05	Involving farmers in the breeding process	0.631
B04	Selecting for local adaptation	0.556
B02	Breeding neglected crops to improve agro biodiversity	0.554
B11	Breeding cultivars with high nutritional quality	0.488
B21	Organic breeding is key for improving the performance of organic agriculture	0.392
B10	Breeding cultivars with good taste	0.361
B16	There is a lack of adapted rules to register varieties suitable for organic growing conditions	0.341
<b>B-II</b>	<b>Knowledge gaps how to breed under organic conditions</b>	
B14	There is a lack of knowledge in our company of organic agriculture breeding goals/criteria	0.832
B13	There is a lack of knowledge in our company on the management of organic breeding field trials	0.679
B15	There is a lack of knowledge in our company of potential organic markets	0.673
B17	There is a lack of knowledge in our company on financing models of dedicated organic breeding programmes	0.585
B19	We do not have an organic breeding programme because we cannot use all available breeding techniques in organic breeding	0.492
<b>B-III</b>	<b>Breeding for traits needed in organic farming</b>	
B12	Meeting the demand of organic production	0.737
B09	Breeding cultivars that are fully suited for organic growing conditions	0.660
B06	Collaborating closely with the organic value chain to select best cultivars	0.596
B11	Breeding cultivars with high nutritional quality	0.442
B01	Protecting our crop germplasm/maintaining plant genetic resources	0.363
<b>B-IV</b>	<b>Targeting conventional breeding goals</b>	
B23	It is sufficient to test conventionally bred cultivars for their suitability under organic growing conditions	0.631
B20	The organic market is too small to justify separate breeding	0.618
B22	The best cultivars for conventional farming are also the best cultivars for organic farming	0.603
B21	Organic breeding is key for improving the performance of organic agriculture	-0.512
B16	There is a lack of adapted rules to register varieties suitable for organic growing conditions	-0.349
<b>B-V</b>	<b>Financial barriers to breed under organic conditions</b>	
B18	Low return on investment of dedicated organic breeding programmes prevents our company from breeding organic cultivars	0.673

Factor B-IV indicates a perspective of conventional breeding goals of actors who state that “it is sufficient to test conventionally bred cultivars for their suitability under organic growing conditions” (0.631), they do not see a potential in organic breeding, as the statement B16 “organic breeding is key for improving the performance of organic agriculture” is loading negatively -0.349 and the statement B20 “the organic market is too small to justify separate breeding” is loading 0.618

respectively. Consequently, the statement B21 “there is a lack of adapted rules to register varieties suitable for organic growing conditions” is loading negatively - 0.512, while it was loading positively on factor B-I. They conclude that “the best cultivars for conventional farming are also the best cultivars for organic farming” (0.603) (Table 10).

Factor B-V is independent and solely based on the statement “low return on investment of dedicated organic breeding programmes prevents our company from breeding organic cultivars” (0.673) and refers to financial barriers to breed under organic conditions (Table 10).

To identify if monetary aspects can be related to the ten identified factors, further questions of the survey were analysed. In one of the surveys questions, the respondents were requested to indicate a range of their company’s yearly turnover from seed sales and breeding activities in EU member states and Switzerland for the year 2018 (including turnover from organic and conventional business activities). Possible ranges were from below 500,000 €; 500,000-999,000 €; 1,000,000-4,999,000 €; 5,000,000-9,999,999 €; 10,000,000-49,999,999 €; 50,000,000-99,999,999 €; 100,000,000-149,999,999 € and above 150,000,000 € per year respectively (Table 11).

Table 11 Range of turnover from seed sales (conventional and organic) to factors on organic seed production

Range of turnover from seed sales per year in Euro	Frequency	Percent
< 500,000	69	32.9
500,000-999,999	15	7.1
1,000,000-4,999,999	40	19.0
5,000,000-9,999,999	16	7.6
10,000,000-49,999,999	26	12.4
50,000,000-99,999,999	13	6.2
100,000,000-150,000,000	6	2.9
>150,000,000	15	7.1
Missing	10	4.8
Total	210	100

Additionally, respondents were requested to indicate their company’s gross annual related turnover from organic seed business in percent. Based on the responses, the company’s relevance of the organic business grouped into six levels of relevance in an increasing order from no relevance, minor relevance, medium relevance, moderate relevance, high relevance and very high relevance (Table 12). Ten out of 210 respondents did not indicate a level of relevance. To identify any potential correlation of the ten identified factors derived from exploratory factor analysis a correlation matrix using Spearman rank correlations was developed. Out of the LIVESEED seed supplier and breeders survey three relevant questions were selected for further analysis.

Table 12: Company's relevance of the organic seed and breeding business, ranked by gross annual related turnover from the organic seed and breeding business in Percent.

Relevance of organic seed trade	Frequency
No relevance, as no organic seed is traded (0% gross annual related turnover)	41
Minor relevance (1-25% gross annual related turnover)	108
Medium relevance (26-50% gross annual related turnover)	10
Moderate relevance (51-75% gross annual related turnover)	3
High relevance (76-99% gross annual related turnover)	13
Very high relevance, as only organic seed is traded (100% gross annual related turnover)	26
Missing data	10
Total	210

**Error! Reference source not found.** indicates if there are correlations between the region where organisations are located, if monetary factors, such as yearly turnover from seed sales (conventional & organic), and the relevance of the organic seed and breeding business are related to relevant factors underlining attitudes of actors derived from the principal factor analysis (factors A-I to A-V and B-I to B-V). The analysis reveals that only for factor A-I (demanding more information and support to perform organic seed production) a regional correlation can be identified. Thus, all other identified factors seem to be not related to a certain regional location (**Error! Reference source not found.**).

The yearly company's turnover (including conventional and organic seed sales activities) is correlating significantly with six out of ten identified factors (factors A-I, A-II, A-IV, B-I, B-II and B-III). The smaller the company's turnover, the lower the loadings in the correlation matrix. Factor B-I (strong focus on organic and participatory breeding for diversity) shows a strong negative correlation of -0.504 to companies' turnover indicating a very small yearly turnover, followed by factor A-I (demanding more information and support to perform organic seed production) with a negative correlation of -0.406. Factor B-II (encountering knowledge gaps to breed under organic conditions) is loading -0.308 and factor B-III (breeding for traits needed in organic farming) is loading -0.156 followed by factor A-IV "having trust in the development of the organic seed market". Factor A-II "encountering difficulties in scaling-up organic seed production" is loading positively 0.188 indicating that those actors generate a high yearly companies' turnover.

Looking at the relevance of the organic seed business nine out of ten factors load significantly. Negative loadings indicate a low relevance of the organic seed business, meaning that the main total companies' yearly turnover is generated from sale activities in the conventional farming sector (factors A-II, B-IV, A-V, B-V). While factor A-II "technical and marketing aspects" is loading -0.322. While positive loadings indicate that the main total companies' yearly turnover is generated within the organic seed and breeding business (factors B-I, A-III, B-III, A-IV, A-I).

Table 13: Correlation matrix (Spearman rank correlations) with 1-tailed significance. N indicated number of valid values.

Factor	A-I	A-II	A-III	A-IV	A-V	B-I	B-II	B-III	B-IV	B-V
Region where company is located	Correlation Coefficient 0.145 <sup>*</sup>	-0.054	0.075	-0.058	0.113	0.050	-0.052	0.053	-0.002	-0.049
	Significance (1-tailed)	0.018	0.219	0.201	0.052	0.236	0.228	0.182	0.490	0.242
	N	210	210	210	210	210	210	210	210	210
Companies' turnover	Correlation Coefficient -0.406 <sup>***</sup>	0.188 <sup>**</sup>	0.009	-0.144 <sup>*</sup>	0.052	-0.504 <sup>**</sup>	-0.308 <sup>**</sup>	-0.156 <sup>*</sup>	-0.057	-0.053
	Significance (1-tailed)	<0.001	0.004	0.452	0.021	<0.001	<0.001	0.014	0.213	0.228
	N	200	200	200	200	200	200	200	200	200
Relevance of the organic seed business	Correlation Coefficient 0.143 <sup>*</sup>	-0.322 <sup>**</sup>	0.216 <sup>**</sup>	0.182 <sup>**</sup>	-0.236 <sup>**</sup>	0.305 <sup>**</sup>	-0.013	0.216 <sup>**</sup>	-0.282 <sup>**</sup>	-0.146 <sup>*</sup>
	Significance (1-tailed)	0.019	<0.001	<0.001	0.004	<0.001	0.428	<0.001	<0.001	0.017
	N	210	210	210	210	210	210	210	210	210

A-I Demanding more information and support to perform organic seed production; A-II technical and marketing aspects; A-III Regulatory barriers in organic seed production; A-IV Trust in the development of the organic seed market; A-V Seed health and technical production aspects.

B-I Strong focus on organic and participatory breeding for diversity; B-II Encountering knowledge gaps to breed under organic conditions; B-III Breeding for traits needed in organic farming; B-IV Targeting conventional breeding goals; B-V Financial barrier to conduct breeding under organic conditions.

## 2.4 Discussion

Only Factor A-I (demanding more information and support to perform organic seed production) has a regional component (Table 13). In the literature, there is a need reported for more training in organic seed production to address various challenges faced by organic farmers. Organic farmers, particularly those with larger operations, face difficulties in accessing satisfactory seed genetics (Lyon et al., 2015). The lack of sufficient and comparable data on organic seed production and use is a significant barrier to market development. Current data reporting at the country level is often basic and inconsistent, making it difficult to compare across regions and time periods. Innovative approaches, such as multiple imputation techniques, have been developed to estimate missing values and improve data collection and analysis. Multiple imputation is a statistical technique used to handle missing data, which is a common issue in various fields of research. It provides a way to fill in missing values by creating multiple complete datasets, analysing each one separately, and then combining the results to produce estimates that account for the uncertainty associated with the missing data. These methods have revealed that organic seed demand significantly exceeds supply for most crops, with regional differences in supply levels (Padel et al., 2021; Solfanelli, Ozturk, Dudinskaya, et al., 2022). Furthermore, factor A-I (encountering a demand for more training, financial support, and transparency in organic seed production) correlates with a low companies' turnover (Table 13) indicating that the size of the company may play a role in training needs. This is also reported by Barret et al. (Barrett et al., 2001) who analyse that high certification costs and complex bureaucratic procedures are significant barriers for small companies. Forming producer groups, acquiring external funding, and utilizing national certification bodies can help mitigate these challenges (Barrett et al., 2001).

For factor A-II (technical and marketing aspects) there is a correlation between high companies' turnover and a low level of relevance of the organic seed business (Table 13). This indicates that large companies, who are new to the organic seed market or produce organic seed just to a limited extent encounter difficulties in scaling-up organic seed production. They may struggle to find farmers and suitable organic certified production conditions for seed multiplication. The main challenges are the lower yields associated with organic farming compared to conventional systems and organizational challenges such as insufficient financial resources, higher costs, regulatory inconsistencies, market dynamics, and the need for stakeholder collaboration (Döring et al., 2012).

Factor A-III (regulatory barriers in organic seed production) correlates with a high relevance of the organic seed business, indicating that companies who trade organic seed face the challenge that the availability of derogations for non-organic seed reduces the pressure on farmers to use organic seeds, which in turn diminishes the demand and investment in organic seed production and breeding (Döring et al., 2012; Padel et al., 2021). Phasing out derogations on non-organic seed is a complex

but achievable goal that requires coordinated efforts across various stakeholders. Economic impacts on farmers can be mitigated through subsidies and price premiums (Winter, Grovermann, Orsini, et al., 2021), while social norms and consumer expectations can drive increased organic seed use (Orsini et al., 2020). Continuous stakeholder commitment and progress monitoring are crucial to ensure the successful transition to organic seed use by 2036 (Schäfer et al., 2022, 2024).

Factor A-IV (trust in the development of the organic seed market) correlates with a medium size of companies' turnover and a medium level of relevance of the organic seed business indicating that those actors trade both, organic and conventional seed and can be associated with small and medium companies. Interestingly those actors don't encounter relevant difficulties to navigate through the organic seed market. Offering both, organic and conventional seed could allow actors to become more independent from fluctuating organic seed demand as farmers require a wide selection of suitable varieties with specific traits like stress tolerance and pest resistance with a limited availability of organic seeds for certain crops. Furthermore, in a well-developed organic seed sector farmers use the national organic seed database as a source of information, and respond to the increasing organic seed supply by using less non-organic seed (Schäfer et al., 2024).

Factor A-V (seed health and technical production aspects) correlates with a low level of relevance of the organic seed business, indicating that companies who just start to work on organic seed production face several technical challenges, such as seed-borne pests and diseases and storage and seed treatments. The prohibition of synthetic chemicals in organic farming increases the risk of diseases, particularly for biennial crops like carrots and onions, which are more susceptible to infections over their extended growing periods (Winter et al., 2023). Seed-borne diseases require special attention, as they can significantly impact seed quality and crop yields (Kim et al., 2022; Kolašinac et al., 2018; Wood, 2003). Maintaining high-quality standards for organic seeds is challenging. Organic seeds often face higher contamination risks from weed seeds and pathogens compared to conventional seeds (Kim et al., 2022; Kolašinac et al., 2018; Wood, 2003). This is exacerbated by the lack of effective disease control measures in organic systems, making it difficult to produce seeds that meet the same quality standards as conventional seeds (Groot et al., 2004; Lammert van Beuren, 2003). Organic seed production is frequently more expensive than conventional production due to factors such as lower yields, increased labour demand for disease management, and the need for specialized practices that do not rely on chemical inputs (Groot et al., 2004).

Factor B-I (strong focus on organic and participatory breeding for diversity) relates with a strong negative correlation of -0.504 to companies' turnover indicating a very small yearly turnover and a strong positive correlation of 0.305 to the relevance of the organic seed business. Thus, mainly small companies and non-profit breeding initiatives aim to breed organically, which could lead to the assumption that organic breeding is a niche business model. Though it is questionable if the concept of organic breeding will be able to deliver a broad range of varieties. However,

these initiatives reflect a growing recognition of the importance of organic breeding in supporting sustainable agriculture (Winter, Grovermann, Aurbacher, et al., 2021). By addressing specific needs within organic farming systems and fostering collaboration among stakeholders, these programs aim to enhance the resilience and productivity of organic agriculture while promoting biodiversity and environmental stewardship (ECO-PB, 2012). Organic heterogenic material (OHM), often referred to as organic populations, presents unique challenges in terms of certification and intellectual property rights. OHM refers to a diverse group of one of the same crop species that are not uniform and consist of multiple genotypes/lines (European Union, 2018). They are typically bred to adapt to specific local conditions and promote biodiversity. Heterogeneous populations, such as composite cross populations (CCPs) of spring barley, have shown significant advantages over homogeneous varieties (Legzdina et al., 2022). These include improved yield stability, nitrogen utilization efficiency, and resistance to stress in organic environments. CCPs may also demonstrate better performance in terms of protein content and grain weight compared to mixtures of their parent varieties, suggesting that heterogeneous populations are valuable alternatives for organic and low-input farming systems (Legzdina et al., 2022). Unlike conventional varieties that can be registered and certified, organic populations do not meet the criteria for variety registration under existing agricultural regulations. This means they cannot be officially classified as a distinct variety and breeders cannot retrieve royalties or other financial benefits typically associated with registered varieties (UPOV, 2002). This poses a challenge for breeders who invest time and resources into developing these populations. However, the inability to claim exclusive rights over organic populations encourages more open-source breeding approaches, where knowledge and genetic resources are shared among farmers and breeders (Kotschi et al., 2022). Encouraging collaborative breeding efforts and open-source approaches, for instance through public funding can help maximize the benefits of these diverse plant populations while addressing the limitations associated with their certification status (Osman & Chable, 2007; Serpolay-Besson et al., 2014). This also refers to factor B-V where actors encounter financial barriers to breed under organic conditions. By engaging private companies, especially those committed to sustainability, additional funding could be retrieved. For example, supermarkets and food companies may invest in breeding projects that align with their product offerings (Winter, Grovermann, Aurbacher, et al., 2021).

Similar to factor B-I also factor B-II (encountering knowledge gaps to breed under organic conditions) negatively correlates of -0.308 with companies' turnover, indicating that those actors work in small companies or non-profit breeding initiatives, but don't breed under organic conditions as they are not familiar with the principles of organic farming. Factor B-II (encountering knowledge gaps to breed under organic conditions) may relate to actors of small and mediums sized companies that are actively promoting their plant genetic material to organic farmers but do not necessarily conduct all breeding steps from crossing to selecting

under organic conditions. While those actors loading on factor B-IV (targeting conventional breeding goals) don't have a high involvement in the organic seed business at all.

## **2.5 Conclusion**

Seed supplier and breeder face several challenges in providing organic seed and suitable varieties for the organic farming sector in Europe. While smaller companies may encounter financial difficulties and a higher need in training, larger companies seem to encounter technical and organisational challenges, such as seed health constraints, lower yields and additional administrative as well as logistical burdens in organic certification and storage. In the context of breeding for the organic farming sector the research shows that mainly very small companies, non-profit initiatives and research institutes perform organic breeding or participatory breeding approaches with a strong focus for diversity. Despite these challenges, there are opportunities for growth. Phasing out derogations for non-organic seeds and providing subsidies could encourage organic seed use. Continuous stakeholder commitment is crucial for a successful transition to organic seed production. Additionally, companies that offer both organic and conventional seeds can navigate market fluctuations more effectively. Addressing technical and regulatory challenges will be key to developing a robust organic seed market that supports sustainable agriculture and meets consumer expectations.

### **Author Contributions**

Conceptualisation: Freya Schäfer; Data curation: Freya Schäfer, Xenia Gatzert, Francesco Solfanelli, Raffaele Zanolì, Eva Winter, Susanne Padel, Maaïke Raaijmakers; Data analysis: Freya Schäfer; Funding acquisition: Monika Messmer; Methodology: Freya Schäfer; Project administration: Freya Schäfer; Supervision: Monika Messmer; Writing – original draft: Freya Schäfer; Writing – reviewing & editing: Freya Schäfer, Xenia Gatzert, Francesco Solfanelli, Raffaele Zanolì, Eva Winter, Susanne Padel, Maaïke Raaijmakers, Monika Messmer. All authors have read and agreed to the version of the manuscript.

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### **3. Trends in Use of Crop Cultivars from Organic and Conventional Seed Multiplication: Moving Toward 100% Organic Seed Use in German Organic Agriculture.**

This chapter is based on the following paper:

Freya Schäfer, Babette Reusch and Andreas Gattinger. "Trends in Use of Crop Cultivars from Organic and Conventional Seed Multiplication: Moving Toward 100% Organic Seed Use in German Organic Agriculture." *Organic Farming*, 10, (2024): 43-68.

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[https://www.acadlore.com/article/OF/2024\\_10\\_1/of100103](https://www.acadlore.com/article/OF/2024_10_1/of100103)

#### **Abstract**

In compliance with European Regulation (EC) 2018/848, organic farming practices necessitate the use of organically produced seeds when available. When suitable organic seeds cannot be sourced, farmers may seek an exemption permitting the use of non-organic seeds. This study examines data from the German national organic seed database to assess trends in the use of crop varieties originating from both organic and conventional seed production. Findings reveal that the diversity of cultivars produced organically is expanding across 15 of the 17 analyzed crops. Correlation analysis suggests that as the availability of organic cereal seed cultivars rises, recorded in the national database, the demand for derogations to use conventional cereal seed cultivars decreases, and vice versa. This positive development in the organic seed sector implies that farmers are adapting their practices in response to the expanding supply of organically multiplied cultivars available through the national database. Nevertheless, challenges such as crop diseases and production limitations in organic cereal seed multiplication can lead to supply deficits, which subsequently result in increased derogation requests for non-organic seeds in the following year. The findings underscore the importance of ensuring robust multiplication of organic cereal seeds to increase the supply, leading to higher adoption of organic seeds and a reduction in derogation requests for non-organic seeds. This study contributes to understanding the impact of supply trends on farmer behavior and highlights the need for further strengthening organic seed multiplication to facilitate full compliance with European organic farming regulations.

#### **Keywords**

Organic seeds; Seed sector; Policy measures; European organic legislation; Seed expert groups

### 3.1 Introduction

The Farm to Fork Strategy of the European Green Deal aims to increase the designated area for organic farming across the entire European Union (EU) by up to 25% by 2030 (European Commission, 2020). Reaching this aim involves tackling the challenge of ensuring an adequate supply of organic seeds (Solfanelli et al., 2021). The use of organic seeds and vegetative propagating materials, also defined as plant reproductive materials, is mandatory in organic farming. The EC 2018/848 (European Union, 2018) and its implementation regulations 2020/464 (European Union, 2020b) and 2022/474 (European Union, 2022) define the conditions that allow for organic farmers to apply for a derogation regarding the use of non-organic seeds without chemical postharvest treatments. Döring et al. (Döring et al., 2012) proposed that, due to the low investment in the past or for other market-related reasons, organic seeds were often not available in sufficient quantity. Thus, European member states report a high number of derogations for the use of non-organic seeds each year (Solfanelli et al., 2021). Solfanelli et al. (Solfanelli, Ozturk, Dudinskaya, et al., 2022) provided the first European-wide estimation of organic seed supply and demand. Their research showed that the share of certified organic seeds, organic farm-saved seeds and non-organic seeds which were purchased differed between crops and regions within Europe. On average, the share of non-organic seeds, granted through derogations, varied between 48.5% in eastern European regions and 18.6% in central European regions. Solfanelli et al. (Solfanelli, Ozturk, Dudinskaya, et al., 2022) also found differences between crop types. Fruit production farms used the most non-organic seeds (41.9%), followed by forages (35.6%), arable farms (29.8%), and vegetable farms (24.6%). The reported high proportion of non-organic seeds showed that the supply of suitable varieties of organic seeds in Europe was still lacking.

The new EC 2018/848 foresees a phasing out of derogations on the use of non-organic seeds by the end of 2036 (European Union, 2018). Padel et al. (Padel et al., 2021) stated that the full enforcement of the regulation to use only organic seeds might have unforeseen consequences, such as a reduction in agrobiodiversity in organic farming, rather than supporting an increase in supply. Padel et al. (Padel et al., 2021) further concluded that, in Europe, the market alone was unlikely to deliver a hundred percent organic seeds, as the market was characterised by its small size, a wide diversity of crops being grown, unresolved technical problems for certain crop species and a limited capacity of breeding varieties adapted to organic farming conditions.

In Germany, organic farming has a long history of development. Germany was the first country to use the EU's funds specifically to promote organic farming, which began as early as the late 1980s (Willer & Schmid, 2016). From 2004 to 2020, the area of organic farmland increased from 767.9 thousand hectares to 1.7 million hectares. This corresponded to a land share of 10.2% in 2020 (BÖLW, 2022; FiBL, 2023). Although this is far from the 25% European Green Deal's goal (European

Commission, 2020) the annual increase in organic land in absolute numbers is among the highest in the EU. Germany is a top-performing country in terms of land used for cereal cultivation and dry pulses, together with France and Italy (Willer et al., 2021). Similar to other EU member states, the German Ministry of Agriculture has representation in the Committee of Organic Production. The Ministry of Agriculture has a mandate to deliver an opinion and vote on a draft of the Council Regulation which involves the implementation of organic production and the labelling of organic products (European Commission, 2021). In most cases, national implementation of the organic farming regulation is organised by the Chambers of Agriculture of the federal states or the agricultural administration of Germany (BMEL, 2022). Due to the frequent lack of available organically produced production material (Groot et al., 2004) derogations on the use of non-organic seeds are granted by the approved control bodies on organic farming and production in Germany (BMEL, 2022). In 2022, nineteen organisations specialising in inspections of organic farms were active (BLE, 2024), controlling 35.7 thousand organic farms across Germany (BÖLW, 2022). Following Article 26, Paragraph 1 of the EC 2018/848 (European Union, 2018) each member state “shall provide a database or a system for the listing of organic and in-conversion seeds, excluding seedlings but including seed potatoes, which is available on its territory”. National databases became mandatory for each country with the implementation of the amended EC 1452/2003, which came into force on January 1, 2004 (European Union, 2003). All entries on the availability of organic seeds and in-conversion seeds constitute the legal basis for the authorisation of the derogations on the use of non-organic seeds. Additionally, all crops and sub-crops can be classified into three categories at the member state level (Table 14). The categories apply different exception systems to non-organic, chemically untreated seeds, including exemplary crop and sub-crop classifications.

Table 14: The classification matrix of three derogation categories for organic seeds in Germany.

<b>Category I</b>	<b>Category II</b>	<b>Category III</b>
Sufficient organic seed from a broad choice of available cultivars	Insufficient quantity of organic seed from limited available cultivars	No or very low quantity of cultivars from available organic multiplication
<i>No derogation</i>	<i>Single derogation</i>	<i>General derogation</i>
Maize ( <i>Zea mays</i> ), Winter rye ( <i>Secale cereale</i> ), Potato ( <i>Solanum tuberosum</i> )	Wheat ( <i>Triticum ssp.</i> ), Barley ( <i>Hordeum vulgare</i> L.), Triticale ( <i>Triticosecale</i> )	Pea ( <i>Pisum medulare</i> ), Garlic ( <i>Allium sativum</i> ), Garden sorrel ( <i>Rumex acetosa</i> )

Source: EU Horizon 2020 Project LIVESEED (LIVESEED, 2017-2021)

For category I crops, referring to Annex III of EC 2020/464 (European Union, 2020b) a sufficient quantity of organic seeds and propagating materials is available. Therefore, derogations for category I crops cannot be granted, following Article 1.8.5.1 of Part I Annex II of EC 2022/474 (European Union, 2022). Exceptions can only be allowed regarding reason “d”: if the cultivar is requested for research; testing in small-scale field trials; cultivar conservation or product innovation (European Union, 2022). In 2019, there were 23 category I crops in the German National Annexe. For category II crops, there is a case-by-case decision; single derogations can be granted by stating the reasons, according to Article 1.8.5.1 of Part I Annex II of EC 2022/474 (European Union, 2022). All crops that are not listed in categories I or II fall under category III. For these crops, not enough organic seeds are available and conventional untreated seeds can be applied through a general derogation (European Union, 2018). Based on the entries in the national database, derogations for non-organic untreated seeds are approved or rejected by the control bodies (BMEL, 2022). In 2005, a German national seed expert group was constituted, hosted by the Chamber of Agriculture in Lower Saxony. The expert group represented relevant actors along the organic seed supply chain, including the approved control bodies, researchers, organic farming associations, organic farming advisors, the German seed association, organic seed suppliers and the seed database manager. The seed expert group consists of two sub-groups covering horticultural and agricultural crops (BMEL, 2022). The mandate of the seed expert group was to advise the regional authorities on classifying all crops according to categories I, II and III. Furthermore, the seed expert group had a mandate to advise the authorities on additional policy measures, such as stricter derogation provisions to accompany the organic seed market’s development (BMEL, 2022). To meet the European Commission’s targets for organic farming expansion (European Commission, 2020) while phasing out the use of non-organic seeds by the end of 2036 (European Union, 2018), this study aims to identify the main factors that affect the number of authorisations for the use of non-organic seeds and planting materials. Therefore, this study determined the changes in the cultivar assortments of organic multiplied seeds available in the national organic seed database as well as the changes in the assortment of varieties used from non-organic seeds authorised via derogations in Germany. In this study, the term cultivar instead of varieties was used, as it refers to a wider range of selection types (such as populations, amateur varieties, land races, etc.) that may suit the needs of the organic farming sector.

Three main hypotheses were proposed in this study:

(i) Germany has an emerging organic seed market to supply farmers with organic seeds in the future. Farmers use the national organic seed database (organicXseeds.de) as a source of information and respond to the increasing assortment of varieties from organic multiplication.

(ii) A higher supply of organic cereal seeds can lead to fewer derogation requests for non-organic cereal seeds.

(iii) Annual changes in cereal organic seed supply can be associated with a one-year lag between overall cereal crop yield outcomes. In high-yielding years, organic cereal seed production and seed certification may be more successful than in years with lower yields.

While the level of market development may affect farmers' uptake of organic seed, the annual supply of seeds from organic multiplication might be affected by various factors, such as adverse weather events or pest and disease outbreaks (Groot et al., 2004). This study discusses market development and the effect of the overall yield on derogation requests. In addition, based on the analysis for each crop, this study discusses the likelihood of reaching the organic regulations' targets of phasing out non-organic seed use (European Union, 2018) and the appropriateness of further (political) measures or provisions.

## 3.2 Materials and Methods

Table 15: Crops selected for the assessment, ordered by crop group, followed by a common name, Latin name, and categorisation in accordance with the derogation system in Germany.

Crop group	Common name	Latin name	Categorisation according to the derogation system in Germany
Cereals	Winter Wheat	<i>Triticum ssp.</i>	Category II - single derogation
	Spring Wheat	<i>Triticum aestivum ssp.</i>	Category II - single derogation
	Winter Barley	<i>Hordeum vulgare L.</i>	Category II - single derogation
	Spring Barley	<i>Hordeum vulgare</i>	Category II - single derogation
	Rye	<i>Secale cereale</i>	Category I - no derogation possible*
	Oat	<i>Avena sativa</i>	Category II - single derogation
	Triticale	<i>Triticosecale</i>	Category II - single derogation
	Spelt	<i>Triticum spelta</i>	Category II - single derogation
	Maize	<i>Zea mays</i>	Category I - no derogation possible*
Legumes	Field Bean	<i>Vicia faba L.</i>	
	Field Pea	<i>Pisum sativum L.</i>	Category II - single derogation
	Lupine	<i>Lupinus</i>	Category II - single derogation
Vegetables	Cabbage	<i>Brassica oleracea</i>	Category II - single derogation
	Red Beet	<i>Beta vulgaris var. conditiva</i>	Category II - single derogation
	Carrot	<i>Daucus carota ssp. Sativus</i>	Category II - single derogation
	Onion	<i>Allium cepa</i>	Category II - single derogation
Root Crops	Potato	<i>Solanum tuberosum</i>	Temporarily Category I - no derogation possible* between February 1 to October 1 of each year

\*Derogations for category I crops cannot be granted, following Article 1.8.5.1 of Part I Annex II of Regulation (EC) No 2022/474 (European Union, 2022). Exceptions can only be allowed regarding reason “d”: if the cultivar is requested for research; testing in small-scale field trials; cultivar conservation or product innovation (European Union, 2022).

Based on a statistical analysis of data obtained from the national organic seed database in Germany for the period 2005-2017, this research was conducted within the framework of the EU Horizon 2020 Project LIVESEED (LIVESEED, 2017). The German national organic seed database (OrganicXseeds, 2025) has two kinds of datasets: (i) the derogation data which includes all relevant information appertaining to individual derogations requested by organic farmers (including requested seed cultivars from conventional multiplication, the crop species, the quantity of seeds requested in metric units or seed-lots, the date of the request, and the justification for the application of the derogation); (ii) the historic data which includes information on the temporary availability of a cultivar over time (total quantities of the available seeds are not recorded). For the analysis, the historic data were filtered for the period of availability of each seed cultivar from organic

multiplication and the total number of seed cultivars available from organic multiplication for each year. Basic seeds used by farmers for seed multiplication were considered separately throughout the analysis and excluded from any further statistical evaluation. To contextualize the national database information, the data on the organic farming area in Germany were obtained from the Agricultural Market Information Society (AMI) (AMI GmbH, 2012, 2014, 2015, 2017, 2018). Data provided by EuroStat was not considered, as EuroStat applies imprecise data groupings (e.g., legumes are grouped together as a single crop group without distinguishing among species such as field pea and bean or lupine). The Agricultural Market Information Society does not provide acreage data for all crop species grown in Germany across the organic systems, but it has substantially more information than EuroStat. This study only investigated the crop species with sufficient data on both the organic farming area (provided by the AMI) and the raw data (provided by the national organic seed database). Based on the given selection criteria, nine cereal crops, three legume crops, four vegetable crops and one root crop were selected (Table 15). For the 17 selected crop species, changes in organic seed supply and the development of derogation requests for non-organic seeds over time were analysed.

Table 16: A list of hypotheses with data analysed and methods applied in this study.

Hypothesis	Data Analysed	Methods
1. <i>The German organic seed market is an emerging market that will be able to supply farmers with organic seed in future. Farmers use the national organic seed database (organicXseeds.de) as a source of information and respond to the increasing assortment of varieties from organic multiplication.</i>	<ul style="list-style-type: none"> <li>• Number of cultivars available from organic seed multiplication per year.</li> <li>• Number of cultivars requested from conventional seed multiplication per year.</li> <li>• Number of derogation requests per crop per year.</li> <li>• Organic farming area in hectare per crop per year.</li> </ul>	Correlation analysis
2. <i>A higher supply of organic cereal seed will lead to a lower level of derogation requests for non-organic cereal seeds.</i>	<ul style="list-style-type: none"> <li>• Compilation of all cereal crops (winter wheat, summer wheat, winter barley, summer barley, rye, oat, triticale, maize, spelt).</li> <li>• Number of cereal cultivars available from organic seed multiplication per year.</li> <li>• Number of cereal cultivars requested from conventional seed.</li> </ul>	Large scale correlation matrix
3. <i>Yearly changes in cereal organic seed supply can be associated with a one-year lag between overall cereal crop yield outcomes. In high-yielding years, organic cereal seed production and seed certification may be more successful than in years with lower yields.</i>	<ul style="list-style-type: none"> <li>• Yields per hectare (conventional and organic yields cumulated) of winter wheat, rye, winter barley, spring barley, triticale, and oat crops.</li> <li>• Number of derogation requests per crop per year for the crops winter wheat, rye, winter barley, spring barley, triticale, and oat crops.</li> </ul>	Correlation analysis

All statistical analysis was performed with the statistical software R, version 3.5.1. To address the first hypothesis, similarities in the development of the organic seed sector were analysed using data obtained from the national organic seed database in Germany (Table 16). This study focuses on several aspects: (i) the development and changes in the organic seed sector in Germany; (ii) trends in the assortments of organic seed supply; (iii) the number of varieties that have been requested from conventional multiplication; (iv) the corresponding number of derogations per crop; and (v) any changes in the crop area over time. These formed the basis for the evaluation and were illustrated for 17 individual crop species. A correlation analysis was carried out to investigate any changes in the supply of varieties from organic multiplication and derogation requests for non-organic seeds, aiming to provide an overview of the market development of the German organic seed sector for cereal seeds. To address the second hypothesis, a correlation analysis was conducted to investigate the strength of the association between the offer of

organic-quality cultivars and the number of requested conventional-quality seed cultivars. For this purpose, data on the compounds of all cereal crops were examined (Table 16). The correlation matrix was used to compare the number of organic-quality seed cultivars of different cereal crops available in the national organic seed database in the period 2005-2017. To account for non-normally distributed data, the correlation coefficients were calculated according to the Spearman's rank correlation test. As discussed by Groot et al. (Groot et al., 2004), adverse weather events or pest and disease outbreaks may cause year-to-year variability in organic seed production. To address the third hypothesis, the effects of these potential factors on the supply of organic seeds were analysed by comparing the yield time series and the number of derogation time series. The yields per hectare data for the period 2003-2016 (from BMEL and the Statistical Offices of the Federal Government and the Federal States (Destatis, 2020; Federal Ministry of Food & Agriculture, 2014, 2015, 2016) for winter wheat, rye, winter barley, spring barley, triticale and oat crops were obtained (Table 16). In this analysis, the average yield per hectare refers to both organic and conventional agriculture. For the period 2003-2016, no separate nationwide yield statistic was available for the organic farming systems. Correlation analyses were carried out to identify any relationships between the annual yield per hectare and the number of derogations for the use of non-organic seeds requested by organic farmers in the following year.

### 3.3 Results

It was found that the availability of cultivars from organic seed multiplication generally increased, and the requests for conventional seeds generally reduced. The results indicated that the German organic seed market showed a positive development in the years 2005-2017. A regression line was fitted and in case of a significant increase, the p-values (referring to the F test) were plotted below the x-axis of each graph. Individual crops and a compilation of all cereal crops were analysed. The cereal crops showed the strongest increase in the availability of cultivars from organic multiplication, e.g., winter wheat (from 6 to 61 cultivars), as shown in Figure 11. The scatter plots demonstrated an increasing trend for regression lines for all observed crops, except for cabbage and red beet. However, the short time span limited the use of regression analysis. In summary, a significant increase in the regression lines can be observed in the development of most organic cereal seed supplies in the German national organic seed database in the period 2005-2017. For each crop group, selected examples were displayed to show contrasting results. Further data is available in the appendix (Figure A 1 to Figure A 18) with a summary of German organic farming acreage and number of derogations on the use of non-organic seeds (Table A 1 to Table A 6).

Winter wheat was used as an example (Figure 11 and subgraphs (a) and (b) of Figure 12 to illustrate a significant increase in the supply of cultivars from organic

multiplication and a significant decrease in the number of cultivars requested from conventional multiplication.

Comparable results of increasing assortments of cultivars from organic multiplication were obtained for spring wheat (Figure A 1 and Figure A 2), rye (Figure A 7 and Figure A 8) and triticale (Figure A 11 and Figure A 12). The analysis of spring wheat (Figure A 1 and Figure A 2), winter barley (Figure A 3 and Figure A 4), spring barley (Figure A 5 and Figure A 6), rye (Figure A 7 and Figure A 8), oat (Figure A 9 and Figure A 10) and triticale (Figure A 11 and Figure A 12), showing a decreasing number of cultivars requested from conventional multiplication.

It can be seen from Figure 13 and subgraph (a) of Figure 14 that the number of spelt cultivars available from organic multiplication is low, ranging from 2 cultivars (available in 2008) to 14 cultivars (available in 2014 and 2015).

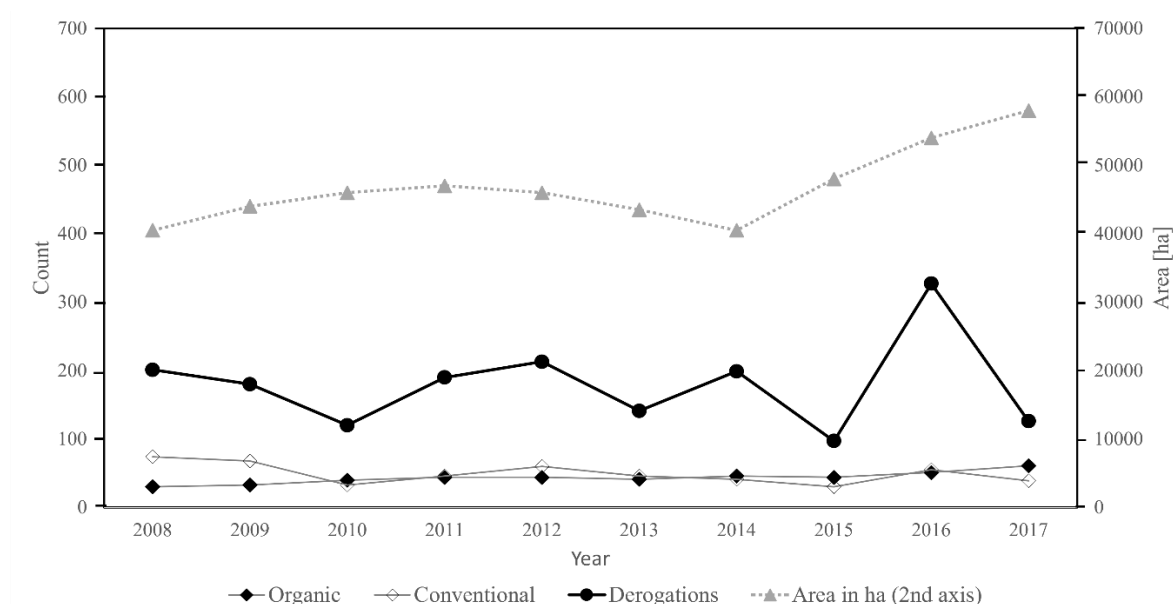


Figure 11 An overview of winter wheat

Note: The left axis displays changes in supply of cultivars from organic multiplication (Organic), changes in cultivars requested from conventional multiplication (Conventional), and the number of derogations requested per year (Derogations). The right axis displays the corresponding organic crop area (Acreage) in hectares per year in Germany.

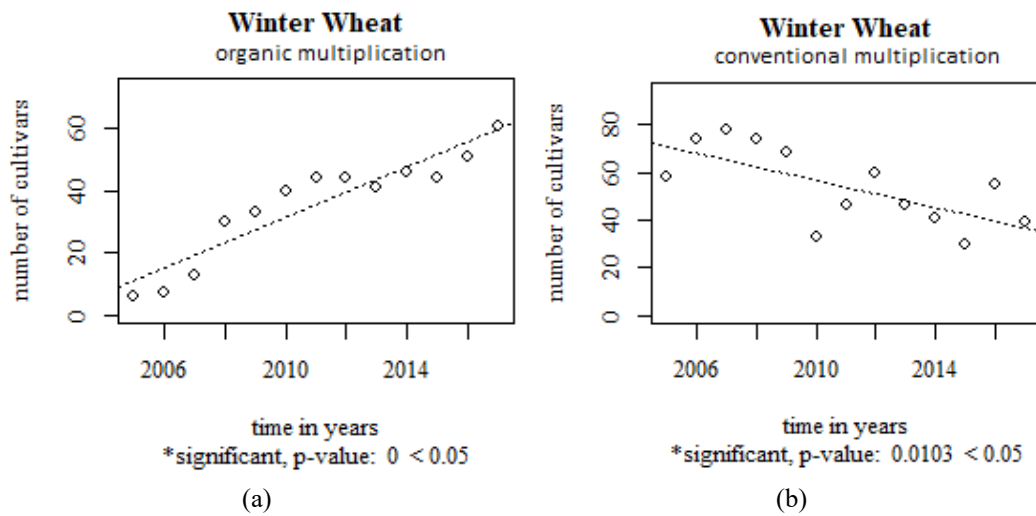


Figure 12 Scatter plots with regression lines for winter wheat from 2005 to 2017 (a) the number of cultivars available from organic multiplication; (b) the number of cultivars requested from conventional multiplication

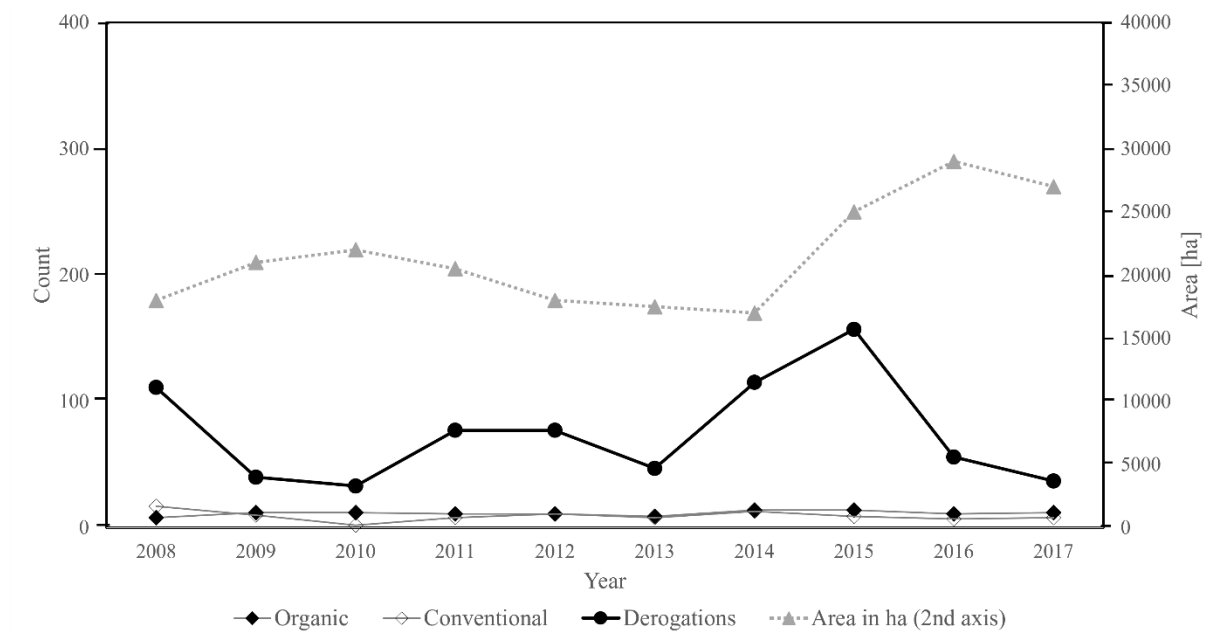


Figure 13 An overview of spelt

Note: The left axis displays changes in supply of cultivars from organic multiplication (Organic), changes in cultivars requested from conventional multiplication (Conventional), and the number of derogations requested per year (Derogations). The right axis displays the corresponding organic crop area (Acreage) in hectares per year in Germany.

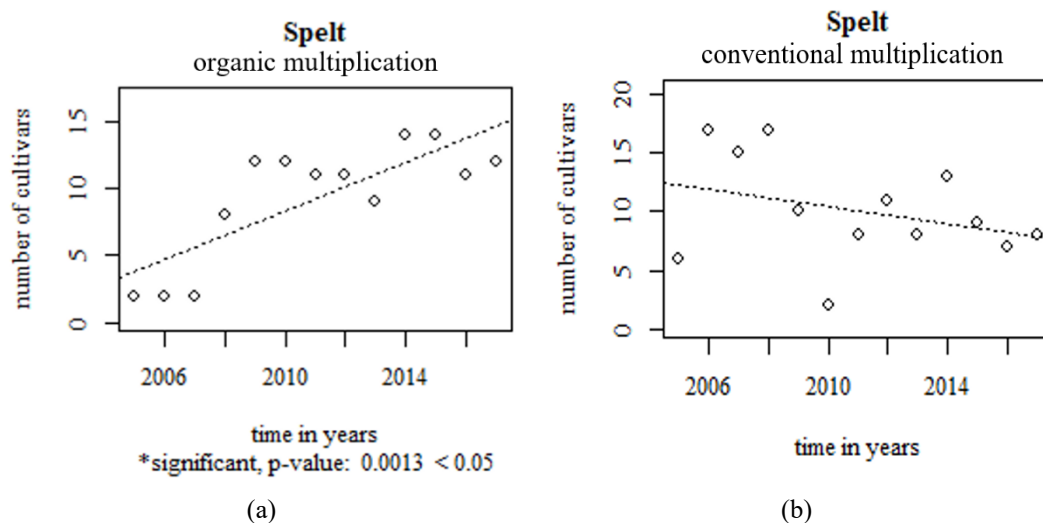


Figure 14 Scatter plots with regression lines for spelt from 2005 to 2017 (a) the number of cultivars available from organic multiplication; (b) the number of cultivars requested from conventional multiplication

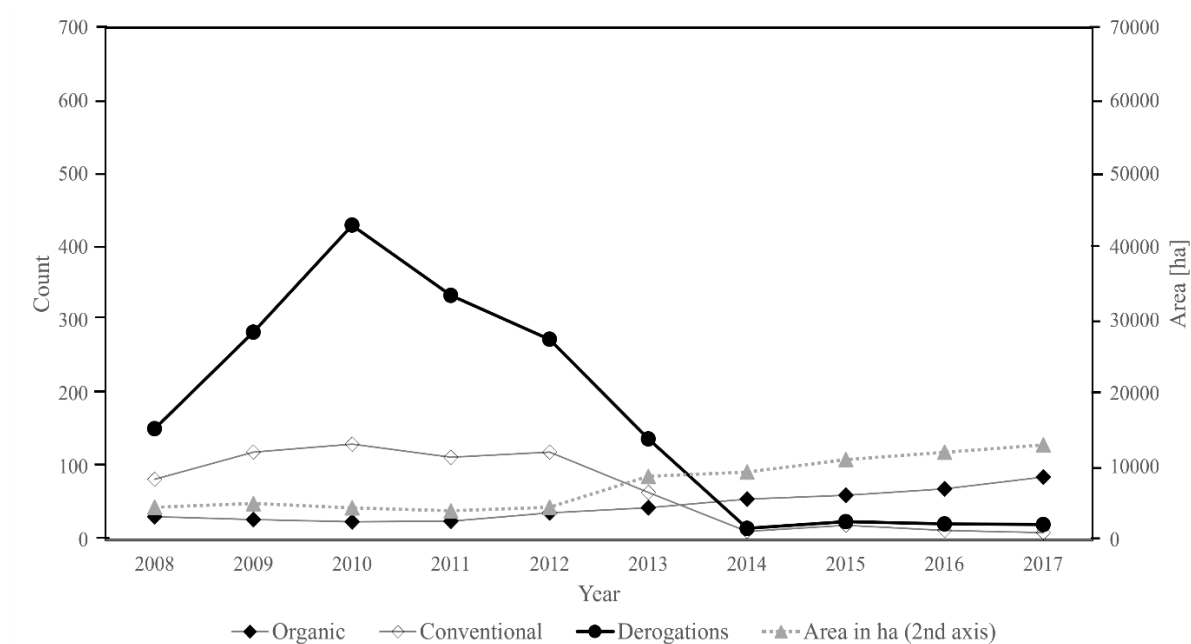


Figure 15 An overview of maize

Note: The left axis displays changes in supply of cultivars from organic multiplication (Organic), changes in cultivars requested from conventional multiplication (Conventional), and the number of derogations requested per year (Derogations). The right axis displays the corresponding organic crop area (Acreage) in hectares per year in Germany.

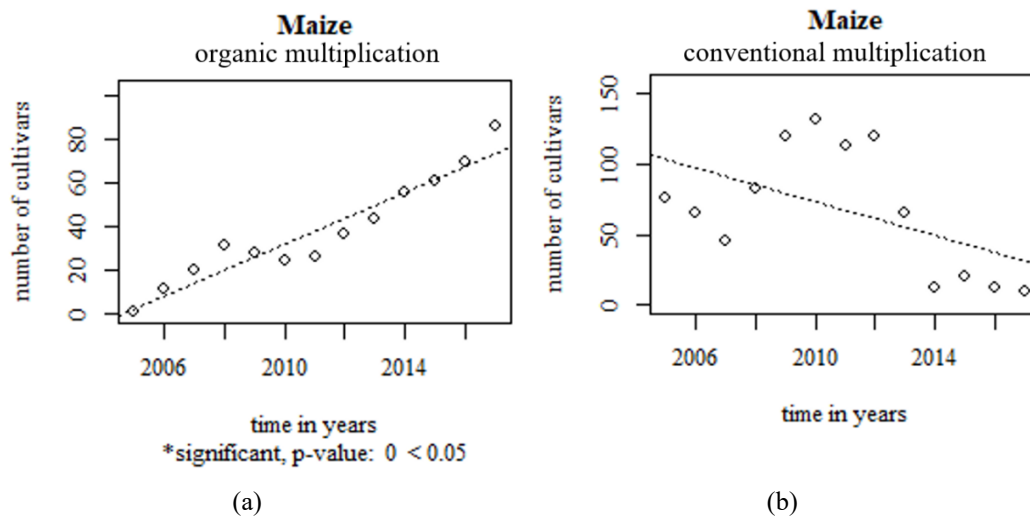


Figure 16 Scatter plots with regression lines for maize from 2005 to 2017 (a) the number of cultivars available from organic multiplication; (b) the number of cultivars requested from conventional multiplication

In 2014, maize was classified as a category I crop, which is reflected by a decrease in the number of derogations (Figure 15). The regression analysis of maize indicates a significant increase in the supply of varieties from organic multiplication, with a decreasing number of cultivars requested from conventional multiplication (subgraphs (a) and (b) of Figure 16).

The compilation of cereals, in which all assessed cereals (winter wheat, spring wheat, winter barley, spring barley, rye, oat, triticale, spelt, and maize) were cumulated, shows an increasing availability of organically multiplied seeds (subgraphs (a) of Figure 17) and a decreasing number of cultivars requested from conventional multiplication (subgraph (b) of Figure 17). There is a positive trend towards a growing organic cereal seed sector in Germany.

In terms of vegetable crops, cabbage and red beet show a contrasting trend in comparison to other crops. A decreasing assortment of organic multiplied cultivars can be observed for cabbage and red beet (Figure 18 and Figure 20) subgraphs (a) and (b) of Figure 19 and Figure 21). The total number of cabbage cultivars available through organic multiplication decreased in the period from 2005 to 2017 (subgraph (a) of Figure 19). While only 6 (in 2017) to 9 (in 2007-2010) cultivars of organic quality were available, the number of cultivars requested from conventional multiplication was between 59 (in 2014) and 268 (in 2008) per year (subgraph (b) of Figure 19).

For red beet, the organic farming area increased from 240 ha in 2008 to 698 ha in 2017 (Figure 20), while only a few cultivars were available from organic multiplication (subgraph (a) of Figure 21).

Figure A 13 to Figure A 16 show a steady growth of carrot and onion in organic farming areas with decreasing trends in the number of cultivars requested from conventional multiplication and a wider choice of cultivars of organic quality.

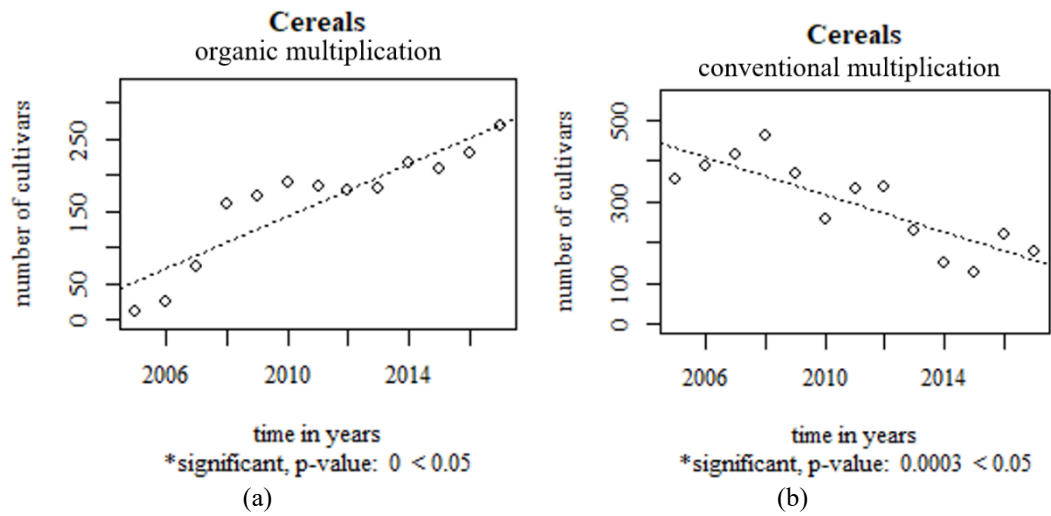


Figure 17 Scatter plots with regression lines for the compound of cereals from 2005 to 2017 (a) the number of cultivars available from organic multiplication; (b) the number of cultivars requested from conventional multiplication

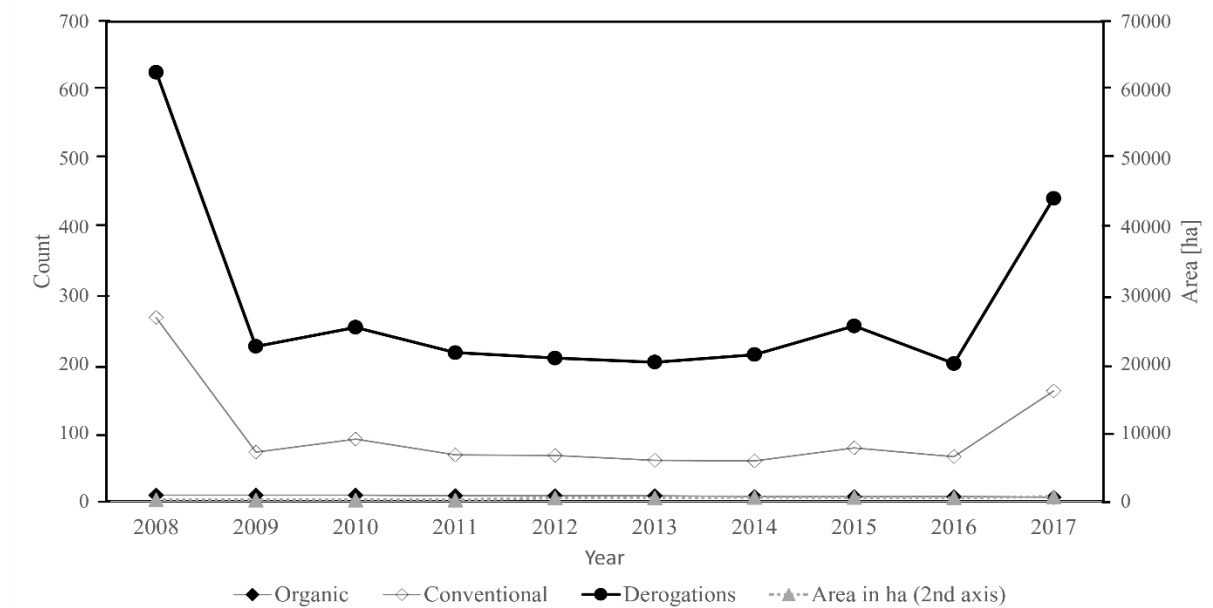


Figure 18 An overview of cabbage

Note: The left axis displays changes in supply of cultivars from organic multiplication (Organic), changes in cultivars requested from conventional multiplication (Conventional), and the number of derogations requested per year (Derogations). The right axis displays the corresponding organic crop area (Acreage) in hectares per year in Germany.

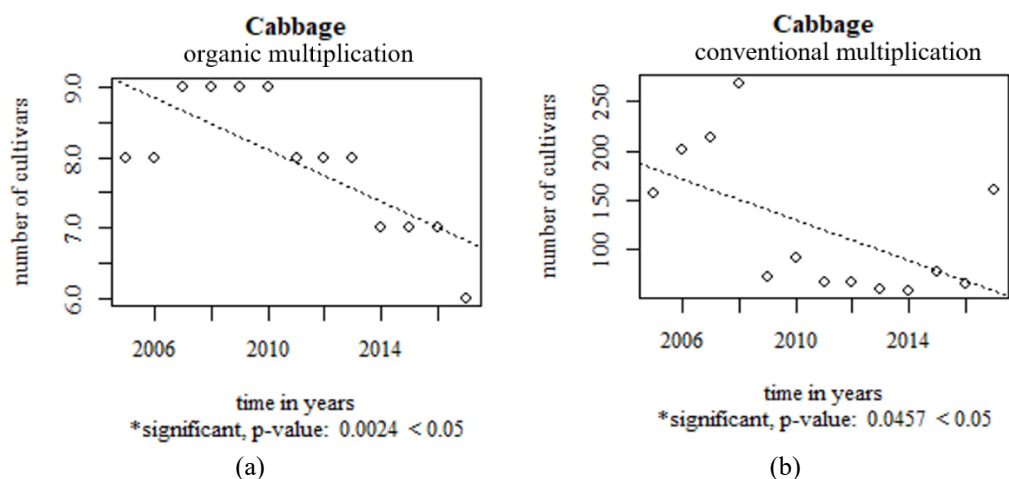


Figure 19 Scatter plots with regression lines for cabbage from 2005 to 2017 (a) the number of cultivars available from organic multiplication; (b) the number of cultivars requested from conventional multiplication

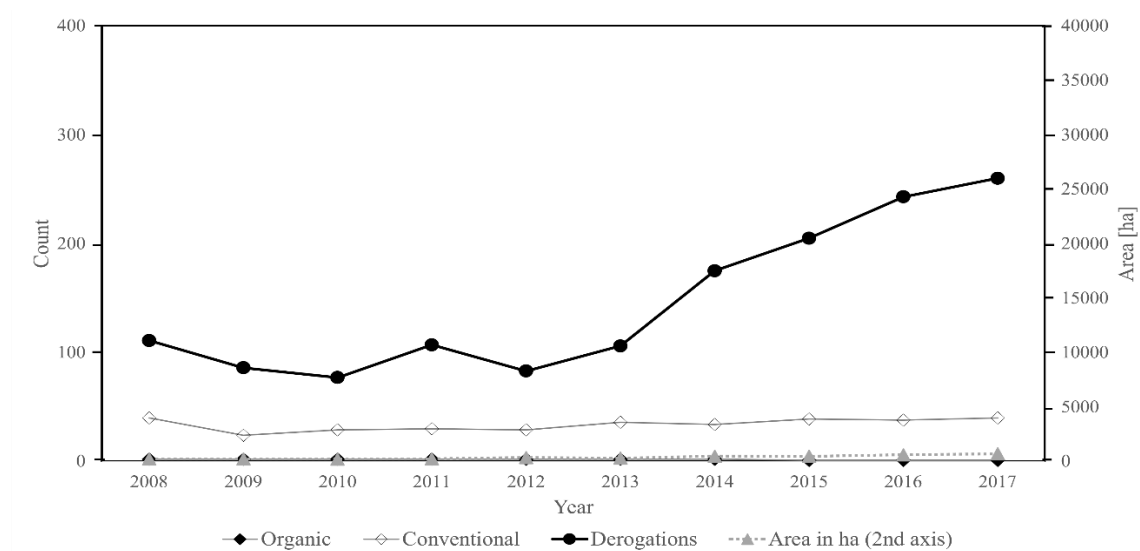


Figure 20 An overview of red beet

Note: The left axis displays changes in supply of cultivars from organic multiplication (Organic), changes in cultivars requested from conventional multiplication (Conventional), and the number of derogations requested per year (Derogations). The right axis displays the corresponding organic crop area (Acreage) in hectares per year in Germany.

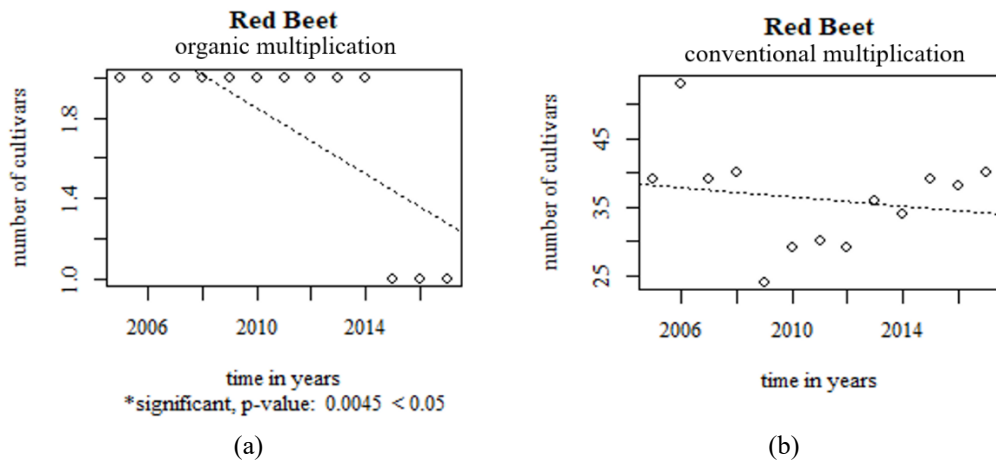


Figure 21 Scatter plots with regression lines for red beet from 2005 to 2017 (a) the number of cultivars available from organic multiplication; (b) the number of cultivars requested from conventional multiplication

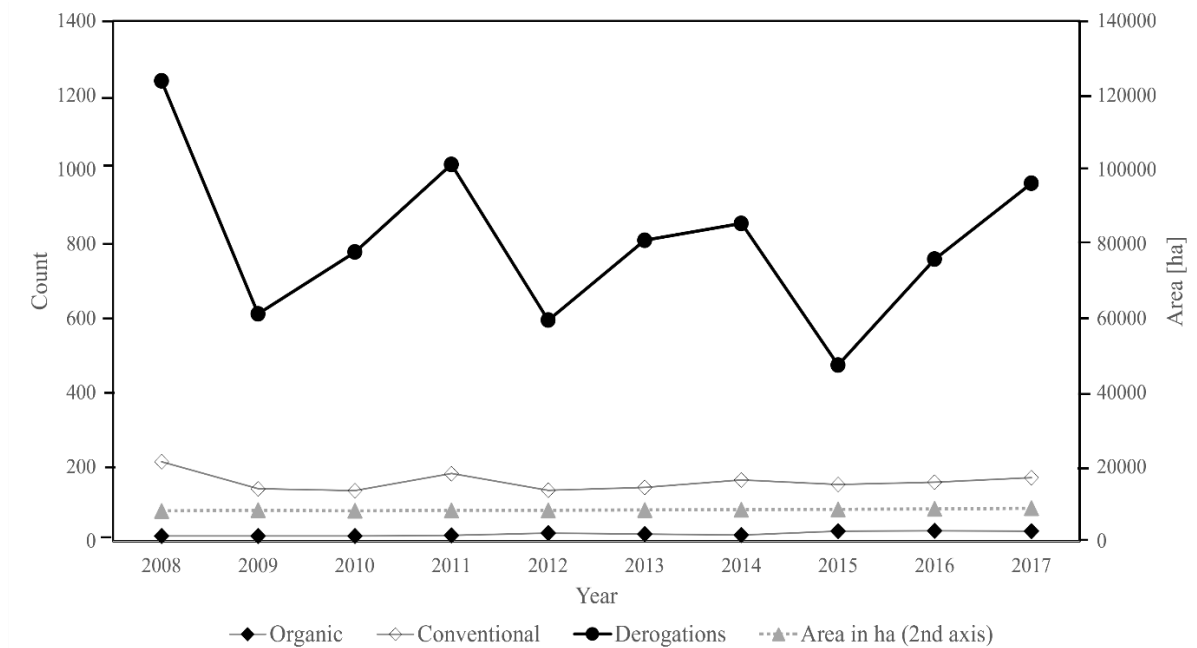


Figure 22 An overview of potato

Note: The left axis displays changes in supply of cultivars from organic multiplication (Organic), changes in cultivars requested from conventional multiplication (Conventional), and the number of derogations requested per year (Derogations). The right axis displays the corresponding organic crop area (Acreage) in hectares per year in Germany.

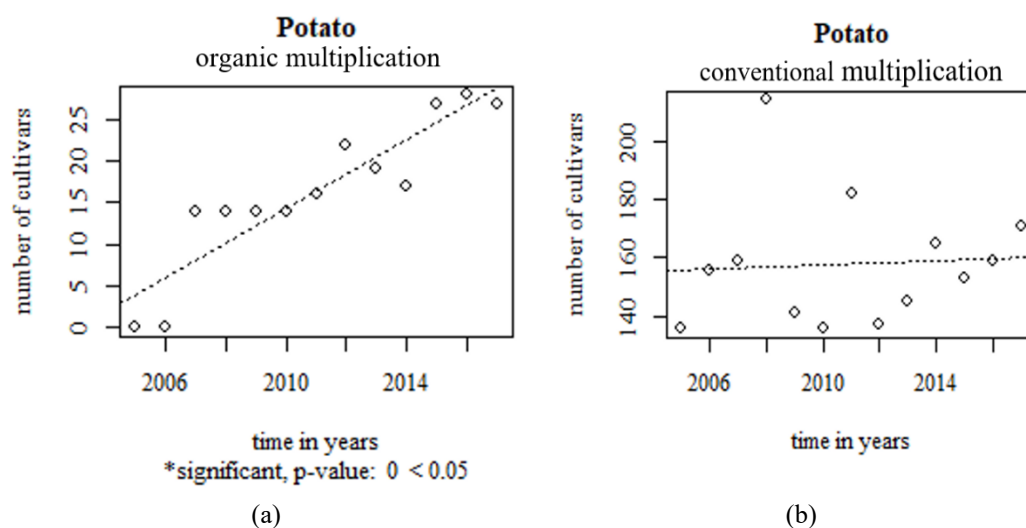


Figure 23 Scatter plots with regression lines for potato from 2005 to 2017 (a) the number of cultivars available from organic multiplication; (b) the number of cultivars requested from conventional multiplication

In 2014, organic seed potatoes were classified as a temporary category I crop. The German national organic seed expert group proposed setting an annual deadline to request derogations on the use of non-organic seed potatoes. This recommendation was made because organic seed potatoes, unlike common seeds, cannot be stored for a longer period if the stock has not been sold within one field season. To incentivise the use of organic seed potatoes each year, organic farmers can request a derogation on non-organic seed potatoes prior to January 31. From February 1 to October 1 of each year, category I applies. Thus, no derogation can be granted, except for Article 1.8.5.1 of Part I Annex II of EC reason "d": if the cultivar is requested for research; test in small-scale field trials; cultivar conservation or product innovation (European Union, 2022). This temporary "no-derogation" period offers production and, more importantly, marketing reliability to organic seed suppliers. The number of derogations did not decrease (Figure 22). However, there was a measurable increase in the choice of organic seed potato cultivars (subgraph (a) of Figure 23) and a request for conventional multiplied cultivars (subgraph (b) of Figure 23).

Figure 24 shows an overview of field bean. For legume crops, both field bean and pea show an increasing trend in organic cultivar choice (subgraph (a) of Figure 25 and subgraph (a) of Figure A 18) and a decreasing number of cultivars requested from conventional multiplication (subgraph (b) of Figure 25 and subgraph (b) of Figure A 18).

Contrary to the field bean and pea, Figure 26 shows an increase in the number of derogations for lupine. The organic cultivar choice of lupine was largely limited, with high annual variations (subgraph (a) of Figure 27). Subgraph (b) of Figure 27 shows no decrease in the number of cultivars compared to conventional

multiplication. Lupine shows an increasing trend in the organic farming area (Figure 26).

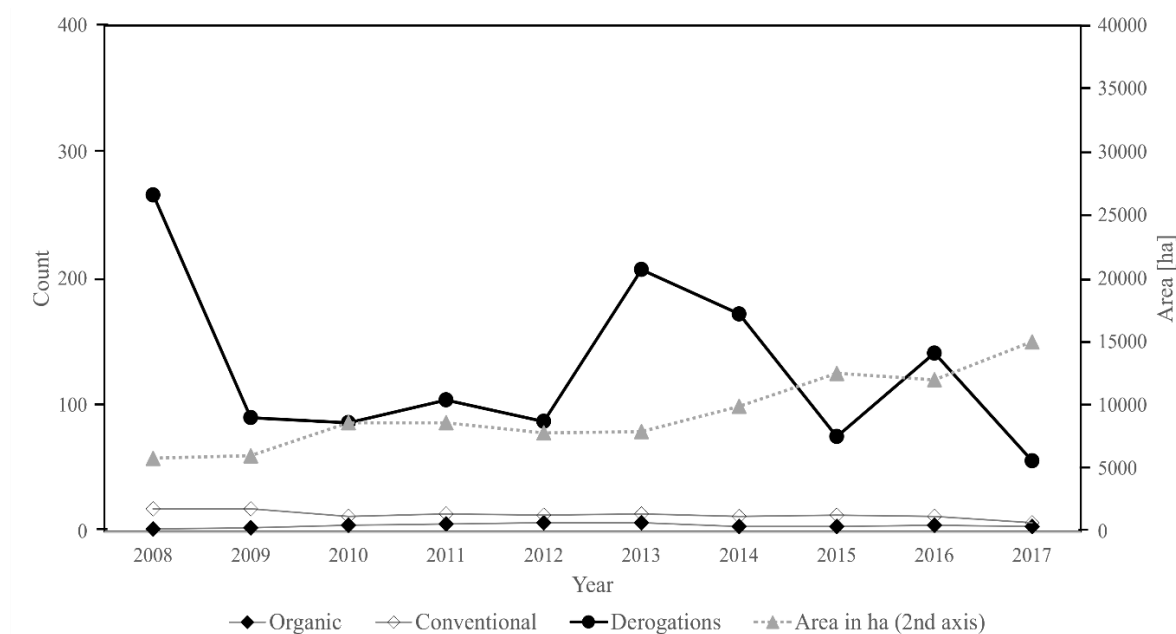


Figure 24 An overview of field bean

Note: The left axis displays changes in supply of cultivars from organic multiplication (Organic), changes in cultivars requested from conventional multiplication (Conventional), and the number of derogations requested per year (Derogations). The right axis displays the corresponding organic crop area (Acreage) in hectares per year in Germany.

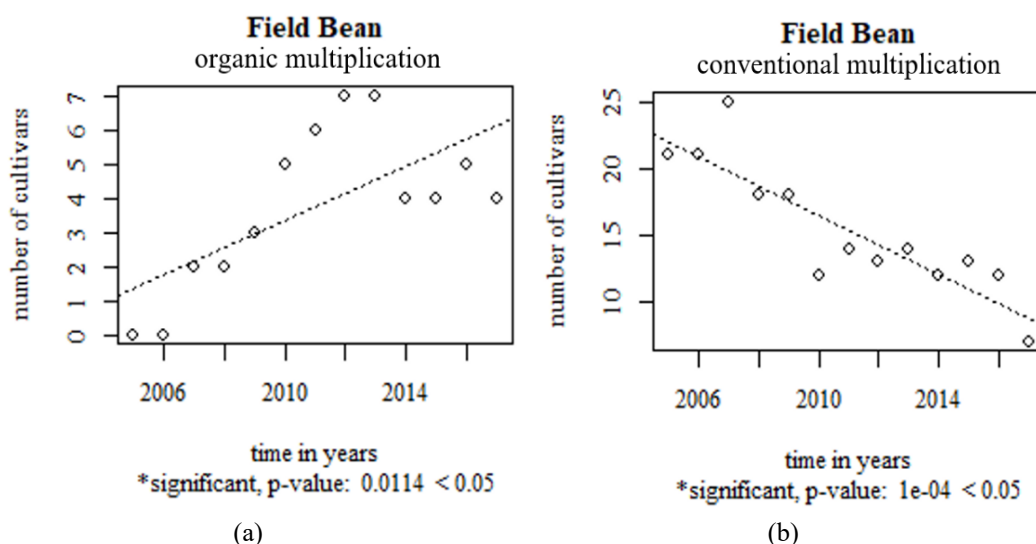


Figure 25 Scatter plots with regression lines for field bean from 2005 to 2017 (a) the number of cultivars available from organic multiplication; (b) the number of cultivars requested from conventional multiplication

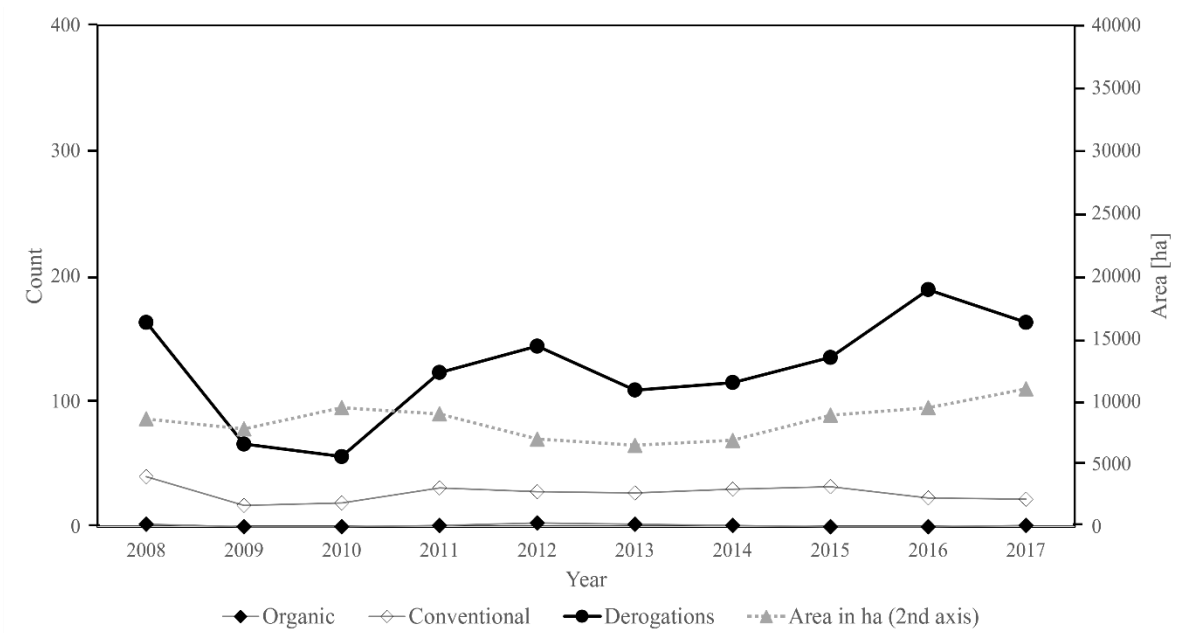


Figure 26 An overview of lupine

Note: The left axis displays changes in supply of cultivars from organic multiplication (Organic), changes in cultivars requested from conventional multiplication (Conventional), and the number of derogations requested per year (Derogations). The right axis displays the corresponding organic crop area (Acreage) in hectares per year in Germany.

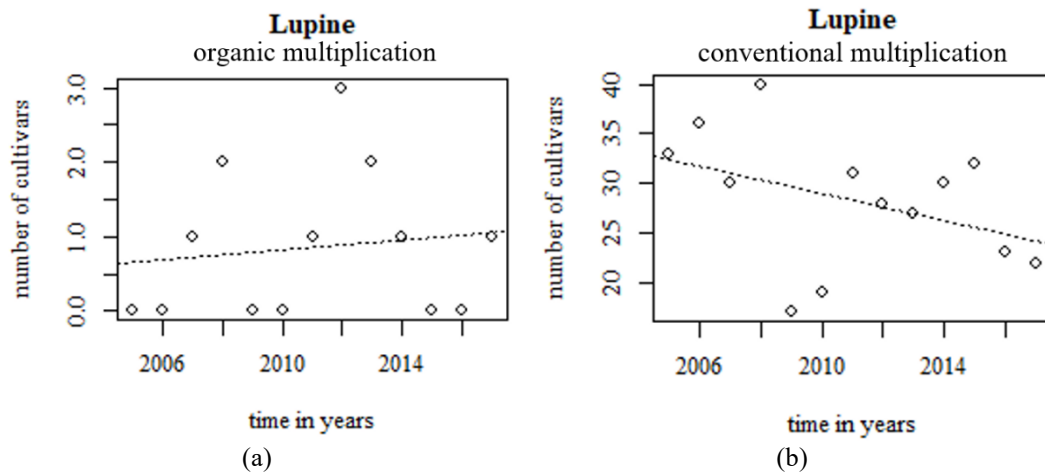


Figure 27 Scatter plots with regression lines for lupine from 2005 to 2017 (a) the number of cultivars available from organic multiplication; (b) the number of cultivars requested from conventional multiplication

## Analysis of Market Development

To determine the strength of the association between the offer of organic-quality cultivars and the number of requested conventional-quality seed cultivars, a correlation analysis was performed. For this purpose, data on the compilation of all cereal crops were examined. As the number of derogations for conventional-quality maize cultivars depended on their classification as a category I crop, maize was excluded from this analysis. As a result, Figure 28 demonstrates a scatter plot with a regression line, with the p-value of the correlation below the x-axis. The scatter plot indicates an approximately linear relationship between the two variables. Based on Spearman's rank correlation, the correlation coefficient could also describe a non-linear relationship. Consequently, a strong negative relationship between the offer of organic-quality cultivars and the number of requested conventional-quality seed cultivars can be observed. The negative correlation shows that the higher the supply of organic-quality cereal seed cultivars recorded in the German national database, the lower the number of requested conventional-quality cereal seed cultivars, and vice versa.

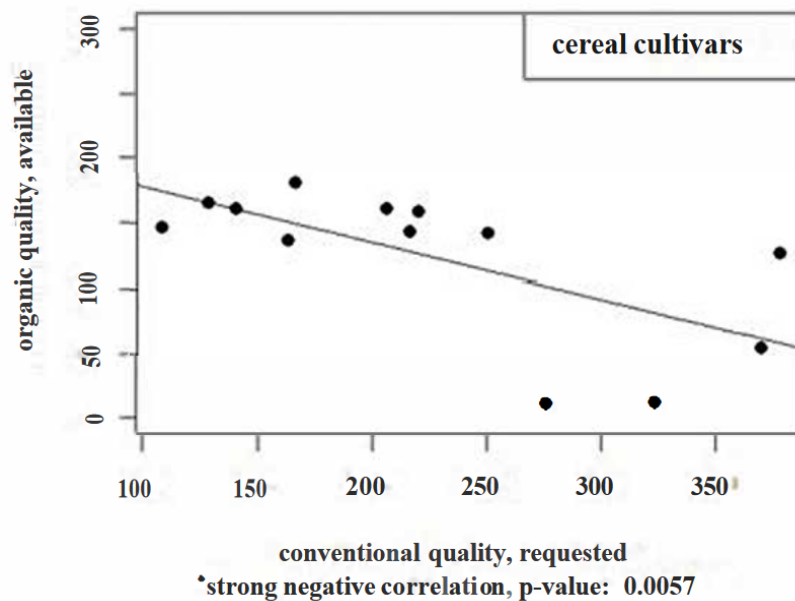


Figure 28 Negative correlation between the availability of organic-quality cultivars and the number of requested seed cultivars from conventional production (maize excluded)

## Analysis of Agronomic Factors Affecting the Number of Derogation Requests for Non-Organic Seeds

A significant increase and cyclical behaviour can be observed for winter wheat, spring wheat, rye, triticale, spelt, maize and the compound of all cereal crops. The regression lines for winter barley, spring barley and oat do not show any statistical significance. No deviations from the normal distribution were found, but the residuals did not follow random patterns, indicating that a better fit should be obtained by using a non-linear model. Thus, the yields (per hectare) were set in accordance with the number of derogations for cereal seeds of conventional quality and plotted over time (Figure 29). No individual yield statistics were available for organic farming between 2003 and 2016. Thus, the cumulative data for conventional and organic farming was used for this analysis. The bottom part of Figure 29 denotes the number of derogations in the period between 2005 and 2017. In 2008, the highest number of derogation requests and, in 2015, the lowest number of derogation requests were reported. The upper part of Figure 19 denotes the yield per hectare, ranging between 51 and 68 dt/ha in the period between 2004 and 2016. The lowest yield per hectare and the highest yield per hectare were recorded in 2007 and 2014, respectively.

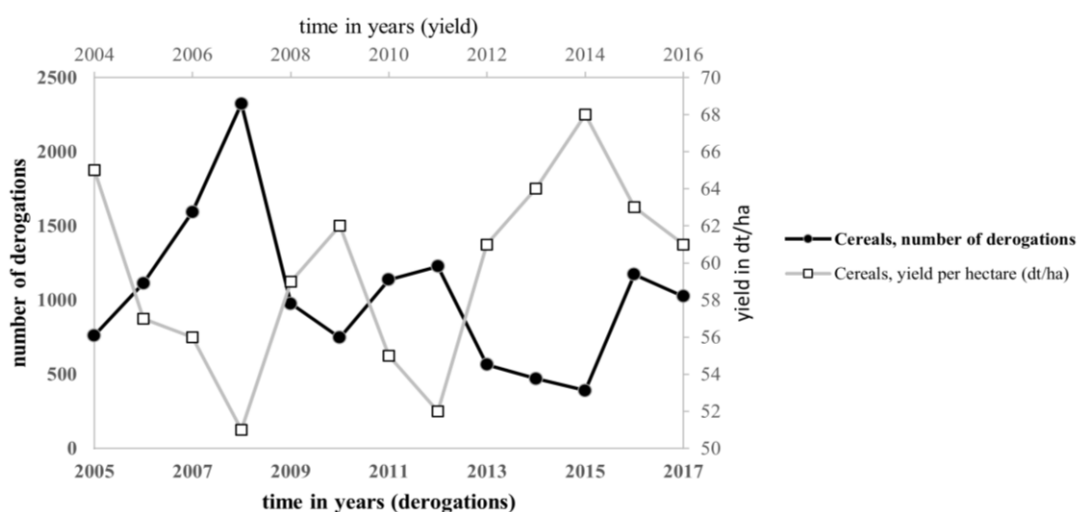


Figure 29 Association between yields per hectare and the number of derogations for cereals in the subsequent year from 2004 to 2017

To measure the strength of the association between the yields per hectare and the number of derogations in the following year, a correlation analysis was carried out. A scatter plot with a regression line can be observed in Figure 30, with the p-value of the correlation below the x-axis. The scatter plot indicates a linear relationship between the two variables.

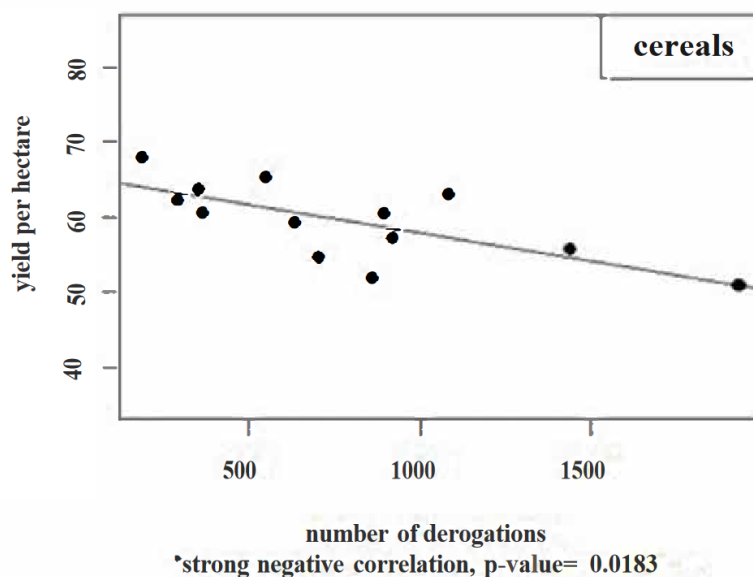


Figure 30 Correlation between yields per hectare and the number of derogations in the subsequent year

A strong linear relationship between the yields per hectare and the number of derogations in the subsequent year can be observed ( $R^2 = -0.71$ ,  $p = 0.018$ ). Therefore, a negative correlation can be described as follows: the higher the yield per hectare, the lower the number of derogations for cereal seeds of conventional quality in the following year, and vice versa (Figure 30).

According to Groot et al. (Groot et al., 2004), organic farming methods offer very few or no direct measures to control pests and disease pressure in cereal fields; thus, yields might depend on annual weather conditions as well as pests and diseases. To test if organic farming is strongly influenced by crop disease pressure, the deviation in 2015/16 was examined in more detail. Figure 29 shows a slight harvest decline in 2015. However, the number of derogations in the following year was recorded as above average. Subsequently, based on harvest reports for the vegetation period 2015/16, it was investigated whether the high number of derogations could be linked to crop disease. For this purpose, the report "2016 Harvest: Quantities and Prices" by the Federal Ministry of Food and Agriculture was examined (AMI GmbH, 2017). The report stated that a mild winter in 2015 favoured the spread of cereal viruses. Furthermore, in May 2016, storms, heavy rainfall, flooding, and hail caused severe damage. In addition to the direct weather-related damage, the harmful effects of fungal diseases and pests were expected to intensify (AMI GmbH, 2017). Figure 30 shows a strong negative relationship between the yield per hectare and the number of derogations in the following year.

### 3.4 Discussion

Given the limited availability of data and the lack of information on the quantities of organic seeds, this study's assessment may have limitations. Changes in the supply of cultivars from organic multiplication indicate that, for the cereal crops, i.e., winter wheat, spring wheat, rye, and triticale (all category II, single derogations), the assortment of organic seed cultivars increased and, simultaneously, requests on cultivars from non-organic multiplication decreased significantly. This suggests that, despite the need for derogations on non-organic seed use in the upcoming years, it is possible to achieve no derogations by 2036. For spelt, it remains unclear whether the 2036 target can be reached as no significant reduction in requests for seeds from conventional multiplication can be observed (subgraph (b) of Figure 14). Thus, for spelt, there is a need to upscaling the assortment of cultivars available through organic multiplication. A separate study should target spelt cultivars used by organic farmers to investigate whether relevant cultivars are not multiplied under organic conditions or whether there is a lack of suitable cultivars available that suit the needs of the organic sector. Incentives to scale up organic spelt seed production and breeding for organic sector activities could help increase the assortment of spelt cultivars in the future. Currently, numerous organic breeding initiatives are striving to register new organically bred spelt cultivars, which could potentially join the market and enhance the existing spelt cultivar assortment (Yussefi-Menzler, 2020). It can be observed that the decisions of the national authorities regarding category I crops (with maize as an example) have an impact on the use of conventionally produced seeds in organic farming and can lead to a sudden drop in the number of derogations. Figure 15 demonstrates that the classification of maize as a category I crop and the concomitant decrease in derogations are not linked to the reduced cultivation of maize crops, as the organic acreage of maize grew steadily between 2012 and 2017. In the case of cabbage and red beet, the selection of organic multiplied cultivars decreases. The limited choice of cabbage cultivars of organic quality could hamper the aim of using 100% organic seeds by 2036. Incentives to increase the choice of cabbage cultivars could be implemented by expanding organic seed multiplication or by strengthening organic breeding that is suitable for organic cabbage production. Considering that there are two cultivars from organic multiplication for carrot and up to six cultivars for onion, the choice of cultivars for these two important crops is still limited and would benefit from further policy measures, such as a subsidy or a price premium, as discussed by Winter et al. (Winter et al., 2023), to upscale the organic seed production and breeding efforts. The seed multiplication of carrot and onion is associated with higher risks and yield losses, as both crops have a biannual seed multiplication cycle. Thus, pests and diseases are the most challenging aspects of organic carrot and onion production (Lammerts van Beuren et al., 2003; Winter et al., 2023). Overall, the data analysis of vegetables reveals annual variations in the supply of seeds from organic

multiplication. Multiple factors might impact the organic vegetable seed supply. It was reported that within the EU, due to shortages in organic vegetable seed production, not all organic seed demand requests could be fulfilled. Suppliers of organic vegetable seeds tend to focus on the countries with the best marketing strategies. Thus, strategic distribution among EU countries might cause fluctuations in organic vegetable seed supply (Vitalis/Enza Zaden, personal communication).

Figure 22 and subgraph (b) of Figure 23 show no decrease in the number of derogations and the request for conventional multiplied potato cultivars. This indicates that, even if the supply of organically multiplied seed potatoes increases over time, there is a need to upscale further organic seed potato production, accompanied by policy measures, thereby ensuring, to a certain extent, production and marketing reliability for organic seed suppliers.

The data analysis of lupine indicates that further policy measures or incentives are needed to upscale organic seed production and breeding, thereby meeting the growing organic lupine seed demand.

There are strong links between the growth of the organic cereal seed cultivar choice and the market analysis in Section 3.2. This means that the organic seed sector has grown at about the same rate for all cereal crops. The number of requested cultivars from conventional multiplication decreases at a similar level for the different cereal crops. Maize was excluded from the correlation matrix because this crop was classified as a category I crop in 2014. The data analysis demonstrates that farmers respond to the organic seed supply as per the German national seed database. The greater the choice of organic seed cultivar, the lower the number of cultivars requested from conventional multiplication. The results might indicate that the farmers' uptake of organic cereal seeds could be directly linked to the seed supply from organic multiplication; however, this relationship is not considered causal. The increase in organic seed demand may also foster investments in the organic seed sector (Osman et al., 2008), further supports the development of the organic seed sector.

Furthermore, this research shows that farmers use the German national seed database as a source of information to see whether organic seeds are available. Solfanelli et al. (Solfanelli, Ozturk, Orsini, et al., 2022) highlighted the importance of a functioning national organic seed database. The analysis in this research supports the results of Solfanelli et al. (Solfanelli, Ozturk, Orsini, et al., 2022) and demonstrates that farmers are open to using available organic-quality cultivars instead of solely relying on their experience and habits regarding cultivar selection. Furthermore, all derogations on the use of non-organic seeds were requested online via the national organic seed database. The advantage of combining information on organic seed supply with the tool used to request derogations is that the database is frequently used as a source of information, increasing the transparency of the organic seed sector.

Nevertheless, the number of derogation requests appears to be directly linked with fluctuations in the organic seed supply. In Section 3.2, the effect of agronomical factors was tested by comparing the yield per hectare with the number of derogation requests in the subsequent year for the cereal crops winter wheat, rye, winter barley, spring barley, triticale, and oat. A strong negative relationship was identified (Figure 30), supporting the hypothesis that years with high yields per hectare are followed by a significantly lower number of derogation requests for non-organic seeds. It can be speculated that during high-yielding years, organic seed multiplication as well as field and seed certification are more successful than in years with lower yields. Furthermore, the organic seed supply shows an increase alongside successful organic seed multiplication, and an increase in organic seed supply is likely to result in fewer cultivars of conventional production being requested (Figure 28). Alternatively, in poor-yielding years, farmers who normally maintain their own seeds might be forced to purchase certified seeds in the following year due to losses of their own seeds. This might lead to an overall higher demand for certified seeds, compensated by higher requests for seeds from conventional certification. In contrast, during strong harvest years, farmers might use their own seeds for reseeded and not be dependent on the seed market or cultivar offers. In summary, farmers respond to organic seed shortages resulting from lower yields per hectare. These might be due to a poor harvest leading to a lower availability of seeds or an insufficient supply of certified organic seeds. Additionally, a high number of derogations in 2016 could be explained by the fact that, in the absence of pesticides, organic farming is affected by crop disease pressures. However, other variables could have an impact on the annual organic seed supply in Germany. Future analysis could involve more robust analytical approaches. Furthermore, additional parameters, such as a comparison of cereal market prices for organic seed supply and a longer time span for the regression analysis, could improve this study.

### **3.5 Conclusions**

Testing of the central hypotheses reveals that Germany has an emerging organic seed market to supply organic farmers with a range of suitable cultivars from organic multiplication for the majority of crops. However, for some crops, particularly the vegetable sector, there are significant gaps in the supply of cultivars from organic multiplication. Thus, in the future, the use of derogations might still be necessary to ensure a suitable cultivar assortment for organic crop production in Germany. For the cereal sector, it can be observed that farmers respond to the supply of cultivars through organic multiplication made available via the national database. Furthermore, certain external (e.g., weather-related) agronomic factors are associated with fluctuating requests for conventional seeds in organic farming. In addition, changing climatic conditions for each crop interfere with the production of organic seeds. As a result, several factors influence the use and

supply of organic or conventional seeds in organic farming. It can be concluded that the statistical analysis of national organic seed database reports provides interesting insights into the organic seed sector. There are different possibilities regarding policy measures which can affect the organic seed market. For instance, the list of category I crops has a high impact on the number of derogations. By supporting organic seed production or breeding efforts, the organic seed supply can be enhanced. If organic seed supply for a certain crop is sufficient, as assessed by the national seed expert group, a category I classification can be considered. A category I classification provides, to some extent, production and marketing reliability for organic seed suppliers and stimulates investment in the organic seed sector. However, for many crop species, especially those not analysed in this study due to a lack of data, the choice of organic-quality cultivars remains limited, making it imperative to scale up organic seed production and breeding for organic farming. The lack of seeds from organic production is also associated with financial and bureaucratic burdens, as organic seed production is at higher risk and needs to comply with the organic certification in addition to the seed certification (Döring et al., 2012; Winter et al., 2023). Additional parameters, such as a comparison of grain market prices for organic seed supply and a longer period for the regression analysis, should be considered in future studies.

#### **Author Contributions**

Conceptualization: Freya Schäfer; Methodology: Freya Schäfer and Babette Reusch; Software: Babette Reusch and Freya Schäfer; Data curation: Babette Reusch; Writing—original draft preparation: Freya Schäfer and Babette Reusch; Writing—review and editing: Freya Schäfer and Babette Reusch; Supervision: Andreas Gattinger; project administration: Freya Schäfer; Funding acquisition: Freya Schäfer; All authors have read and agreed to the published version of the manuscript.

## 4. Securing Commitments from Stakeholders in 10 EU Member States – The Organic Seed Declaration to Foster Stakeholder Involvement

This chapter is based on the following paper:

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### **Abstract**

The new European organic regulation 2018/848 aims to phase out the use of non-organic seeds in organic farming by 2036. At present, achieving this goal in countries with a poorly developed organic seed sector is difficult, and therefore there is a great need to increase organic seed supply by promoting the development of the organic seed sector in Europe. This paper presents a conceptual framework to secure voluntary stakeholder involvement in the process of a gradual increase in the supply of organic seeds for organic farming. Stakeholders showed a high motivation to commit to concrete action points for moving forward. In addition, further actors were involved in the fulfilment of the commitments, a sign of a positive network effect in favour of organic seed production and use. The study indicates application potential and can complement mandatory policy instruments. Further progress monitoring is necessary to ensure that established structures maintain their function, and to keep the shared sense of responsibility alive.

### **Keywords**

Organic seeds; voluntary commitments; stakeholder involvement; policy measures; European organic legislation

### **4.1 Introduction**

In the European regulation (EC) 834/2007 (European Union, 2007) on organic production and labelling, and further specified in its implementing regulation (EC) 889/2008 (European Union, 2008), it is stated that the use of organic seed and vegetative propagating material is mandatory in organic farming. Because for many plant species there is a shortage of organic seed, derogations for the use of chemically untreated non-organic seed can be granted. The option of derogations, however, impedes the development of the organic seed market, and results in a lack of availability (Döring, et al., 2012; Orsini, et al., 2020). The new European

regulation (EC) 2018/848 (European Union, 2018)—which came into force 1 January 2022—foresees a phasing out of these derogations by 2036. To reach the aim of 100% organic plant reproductive material (organic PRM) for all crop species grown on organic farms in the EU, there is an urgent need to mobilize everyone involved—directly or indirectly—in the production and use of organic PRM, i.e., organic farmers and seed producers, control bodies, seed authorities, national authorities, and researchers. Past analysis (Döring et al., 2012) showed that implementing individual measures can increase organic seed supply, but this did not directly lead to a reduction of derogations for the use of non-organic seed. A complex set of factors affect farmers' use of organic or non-organic seeds, with strong regional differences across Europe (Orsini et al., 2020). Aspects that impact organic seed use by farmers include the availability of suitable cultivars, marketing strategies for the organic products, and time since the farm converted to organic production. Thus (Orsini et al., 2020) (p. 11) concludes, that “if derogations for the use of untreated non-organic seed are to be phased out by 2036, the issue of seed use needs to be more widely addressed, beyond the short and specialized organic supply chains”. Therefore, the instrument of a voluntary seed declaration was proposed—a concept based on voluntary commitments from all actors involved as a tool to initiate bottom-up processes, especially in countries with a poorly developed seed sector. According to Lenney & Easton (Lenney & Easton, 2009) (p. 555) commitments are defined as “agreements between two or more social actors to carry out future actions”.

In game theory, joint commitments among all players prior to the game have been shown to increase their payoffs, ultimately reaching a goal more efficiently as if acting individually (Kalai et al., 2007). The concept of voluntary commitments was chosen to be able to respond to the urgent lack of organic PRM in a more cost- and time-efficient way. As the actors are themselves responsible for the content of the seed declaration, voluntary commitments allow flexibility and adaptation to local circumstances and practices (Brown Weiss, 2014). This is crucial as the use of organic PRM is inconsistent across Europe and for the different crop sectors: Orsini et al. (Orsini et al., 2020) find higher values of organic seed use in Northern and Central Europe as compared to Southern and Eastern Europe; and higher values in the vegetable sector, followed, in descending order, by the arable, forage, and fruit sectors.

Besides these advantages, voluntary commitments create the opportunity for network effects by involving further actors in their fulfilment (Lenney & Easton, 2009). In this way, the seed declaration can involve actors beyond those that have been present in its negotiation and can act as a pioneering example in other countries (Brannstrom et al., 2012). The seed declaration, if communicated in simple language to a broad audience, could shape public and political discourse. As a result, consumers could exert a market force, and value chain actors might follow the social pressure in favor of organic PRM (Brannstrom et al., 2012; Brown Weiss,

2014; Sutton et al., 2007). This is important, as farmers' decisions on using organic PRM are often influenced by social norms (Orsini et al., 2020).

From 2003 to 2013, the European Consortium of Organic Plant breeding (ECO-PB, 2013) conducted several stakeholder workshops to foster the development of the organic seed sector. However, mostly the Central European Member States have participated in these workshops and there are only a few other examples of stakeholder involvement. In recent decades, however, voluntary commitments have found their way into environmental law and climate negotiations. These commitments are often industry-driven, involving companies, organizations, networks, but also individual actors (Böhringer & Frondel, 2022; Brown Weiss, 2014; Ramstein, 2012). According to Weiss (Brown Weiss, 2014) (p. 88) this phenomenon is described as "bottom-up empowerment". Apart from that, there are government-led mandatory approaches in the form of regulations or tax-based economic incentives (Alberini & Segerson, 2002). Politicians often welcome voluntary commitments as these allow them to avoid confrontation with industries (Böhringer & Frondel, 2022). Thus, voluntary commitments should not be seen as a replacement for these mandatory approaches, but as a complementary tool (Ramstein, 2012), especially when there is an insufficient political will to implement legislation (Smith et al., 2019). This is particularly the case for organic PRM. The European Commission is showing a certain degree of political uncertainty as the phasing out of derogations may lead to shortages in the organic seed supply—if no complementary measures are taken (Padel et al., 2021). Thus, legislative measures are not implemented, which in turn discourages seed producers from investing in organic PRM (Döring et al., 2012; Winter, Grovermann, Aurbacher, et al., 2021). Analysis conducted within the EU Horizon 2020 project LIVESEED reveals political obstacles and bottlenecks in the implementation of the organic regulation concerning organic PRM (Raaijmakers & Schäfer, 2019). The main obstacle to its implementation is that in most EU Member States the production or use of certified organic seeds is not actively encouraged. The analysis further calls for the implementation of the new organic regulation to include clear rules for the establishment of stakeholder seed expert groups, to monitor the progress of the production and use of organic seed across Europe, and to implement strict national derogation standards (Raaijmakers & Schäfer, 2019). This is illustrated by the example of the organic seed database. According to (EC) 2018/848 (European Union, 2018) and its delegated regulation (EC) 2020/1794 (European Union, 2020a), each EU Member State is required to establish a seed database indicating the availability of organic PRM and in-conversion to organic PRM. However, as the regulation only contains minimal requirements, the implementation of such databases ranges from computerized databases (OrganicXseeds, 2025) to Excel spreadsheets (Solfanelli, Ozturk, Orsini, et al., 2022). With the latter, it is not possible to provide an up-to-date overview of the organic PRM available on the national market, leading to unfounded exemptions for the use of conventional seed (Raaijmakers & Schäfer, 2019; Solfanelli et al., 2021). While mandatory policy instruments are still needed to

reach the aim of 100% organic PRM, voluntary commitments might be a tool to counteract the political stalemate in many EU Member States regarding the production and use of organic seeds. To this extent, voluntary commitments should aim to establish partnerships within and between the seed sector and governments, and to facilitate mutual learning processes and the exchange of best practices (Neumann & Unger, 2019; Ramstein, 2012; Sutton et al., 2007). Due to the non-binding nature of voluntary commitments and to ensure its effective implementation, it is necessary to monitor compliance, report on progress, and ensure transparency and accountability (Brown Weiss, 2014; Lenney & Easton, 2009; Neumann & Unger, 2019).

A successful example of voluntary commitments in the organic food sector is the potato covenant in the Netherlands. The idea of the covenant arose from the extensive damage caused in organic potato production by *Phytophthora* in 2016. In the Netherlands, where the use of copper is prohibited, the only solution against *Phytophthora* is the use of resistant or robust varieties. Thus, 28 stakeholders came together to sign the covenant “accelerated transition to robust potato varieties” with the aim of reaching 100% robust organic potatoes in 2020. To speed up market introduction, stakeholders committed to giving priority to robust varieties in breeding, seed production, cultivation, and sales. Within three years, 25 robust potato varieties could be introduced into the Dutch market by these means. On top of that, a positive network effect could be observed as a similar covenant was signed in Flanders and Wallonia (Heining, 2021).

## 4.2 Material and Methods

The research presented in this paper results from an application study within the EU Horizon 2020 project LIVESEED (June 2017-September 2021) (LIVESEED, 2017). Following a status-quo analysis of organic seed use in all 28 EU Member States, 10 countries were selected based on three criteria: (i) high number of yearly reported derogations for the use of non-organic seed; (ii) limited national availability of organic seed; and (iii) limited data available on the national organic seed market and actors involved. The selected countries—Bulgaria, Estonia, Greece, Hungary, Italy, Lithuania, Latvia, Poland, Romania, and Spain—met at least two out of the three criteria.

The implementation of the concept followed a three-step process consisting of national visits, national workshops, and a final conference (Figure 31). The national visits were organized from September 2017 to September 2018, in cooperation with a national project partner. The aim was to get an overview of the main threats and opportunities. Therefore, one-on-one interviews were conducted with all the relevant stakeholder groups on their attitudes towards organic seeds and how production and use could be stimulated. The outcome were country reports—including results of the previous status-quo analysis—which were published on the

LIVESEED website and disseminated among national actors (LIVESEED Reports, 2018).

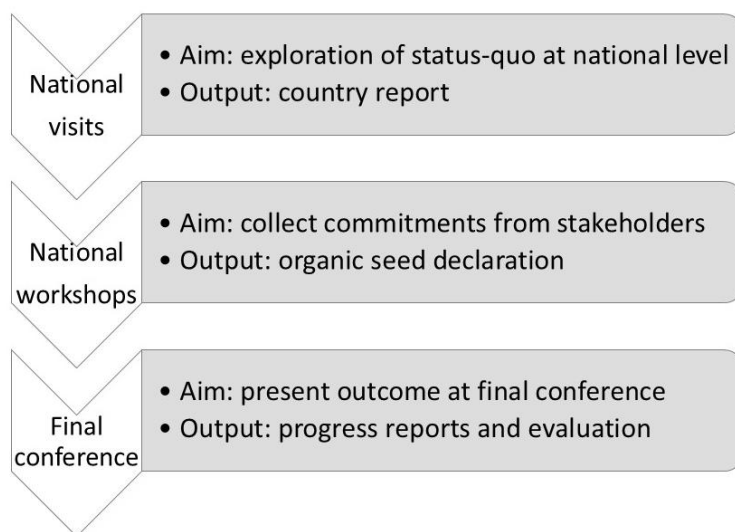


Figure 31 Three-step concept to develop and monitor the national organic seed declarations.

Secondly, from January to October 2019, national workshops were conducted in each of the 10 selected EU Member States—except for the Baltic States, where Latvia, Estonia and Lithuania participated in one joint workshop held in Riga, Latvia. At these workshops, all national organic seed sector stakeholder groups, such as farmers, seed producers, breeders, regional and national authorities, organic control bodies, and researchers were invited. The workshop aimed to collect information on how to make progress and define concrete action points. Therefore, to gain high actor involvement, the concept of the organic seed declaration, based on voluntary commitments from all actors involved, was developed. In a participatory approach, dialogues between all participants were encouraged to create a sense of cooperation to reach a common goal, i.e., to foster the production and use of organic seeds at the national level. The discussion was guided by the following four categories: (i) improvements to national seed databases; (ii) implementation of incentives to increase the production and use of organic seeds; (iii) increasing information on varieties suitable for organic production; and (iv) increasing cooperation among the stakeholders. The outcome of the workshops was the organic seed declaration, containing action points and policy measures which are formulated by the participants in the form of a covenant. This way, the declaration acknowledges the unique characteristics of the participants and the conditions in the respective country. Ideas for actions mentioned during the workshop for which there were no volunteers were not included in the declaration. At the end of each workshop, the participants were asked to show their commitment by signing the declaration, which is not legally binding. To trigger a positive network effect, efforts were made to ensure transparency and raise awareness by communicating the seed declaration using

different channels such as social media and the LIVESEED website (LIVESEED Reports, 2019).

The final step was the organization of a final stakeholder conference, held online in November 2020, in which the national project partners from the 10 involved EU Member States presented the implementation of action points. These were evaluated and compiled in national progress reports (LIVESEED Reports, 2020).

When assessing the impact of voluntary commitments on the organic seed sector, Alberini & Segerson (Alberini & Segerson, 2002) propose to measure its effectiveness and efficiency. The work presented focuses on effectiveness and hypothesizes that the seed declaration, based on the concept of voluntary commitments, is an effective tool to increase the level of organic seed production and use in the respective country. To measure effectiveness, Alberini & Segerson (Alberini & Segerson, 2002) propose to take into account three factors: the number of participants, the extent to which the action points are achieved by the participants, and the impact on the organic seed sector. Taken alone, the participation level is an insufficient measurement, but it gives a good first indication and allows us to analyze participation incentives for future interventions. With regard to the other two factors, a regular reviewing and monitoring process was set up. One year after each workshop, a progress report was written to analyze and evaluate which of the intended action points and policy measures have been implemented. These progress reports create a follow-up of the workshop and ensure that the realization of the various action points is monitored. In the analysis, the participation rate and the number of commitments made in the seed declaration is assessed. Additionally, with the help of the progress report, the individual action points were evaluated and the share of fulfilled, partly fulfilled, and not fulfilled commitments calculated. The analysis was based on the four categories that guided the group discussion. As these categories were extracted from stakeholder interviews, a deductive approach to extending prior research was chosen (Hsieh & Shannon, 2005). The deductive approach allows moving from the more general categories to the more concrete and specific action points (Graneheim et al., 2017). Thus, the individual action points of the seed declaration were allocated to the four categories. Action points that did not fit into any of the categories were marked as such. In addition, the wording and the complexity of the commitments and background information on the situation in each country were analyzed.

However, the high diversity of organizational structures and differences between countries limit the ability to directly compare the commitments and draw common conclusions. The presented paper focuses on the analysis of the theoretical concept that voluntary commitments can lead to an increase in stakeholder involvement, which then indirectly leads to an increase in organic seed supply and use. The possibility of an extensive country-wide analysis is limited, as this would leave out the individuality of each country.

### 4.3 Results

The number of participants per national workshop varied per country, with the lowest number of participants reported in Estonia (4) and the highest number in Italy (61). Figure 32 illustrates the composition and number of stakeholders per country. Individuals who solely participated in the workshop for facilitation reasons were excluded from Figure 32. Stakeholders were grouped into five categories: (i) authorities (e.g., national ministry, regional ministry, seed database manager, seed certification authority, control body); (ii) research and breeding (e.g., researchers from universities, breeding institutes, or breeding organizations); (iii) seed supply (e.g., seed producers, seed traders, seed associations, seed banks, seed savers); (iv) seed use (e.g., farmers, farming associations, farm advisors) and (v) others (e.g., food traders, civil society organizations, journalists, industrial investors). Actors falling into more than one group, e.g., an organic farmer who also produces organic seed for retail, were grouped according to the main focus of their activities. All stakeholders who participated in the workshops joined the invitation organizer. The set-up of the workshop was envisaged to ensure a balanced composition between stakeholders, except for the stakeholder group “others”. Depending on the organizational structure of each country and responses from invited actors, a balanced composition of stakeholders was not always attainable. With higher representation from the authorities (e.g., Italy), research and breeding (e.g., Hungary), the seed sector (e.g., Spain), or farmers (e.g., Greece) were recorded in the other workshops.

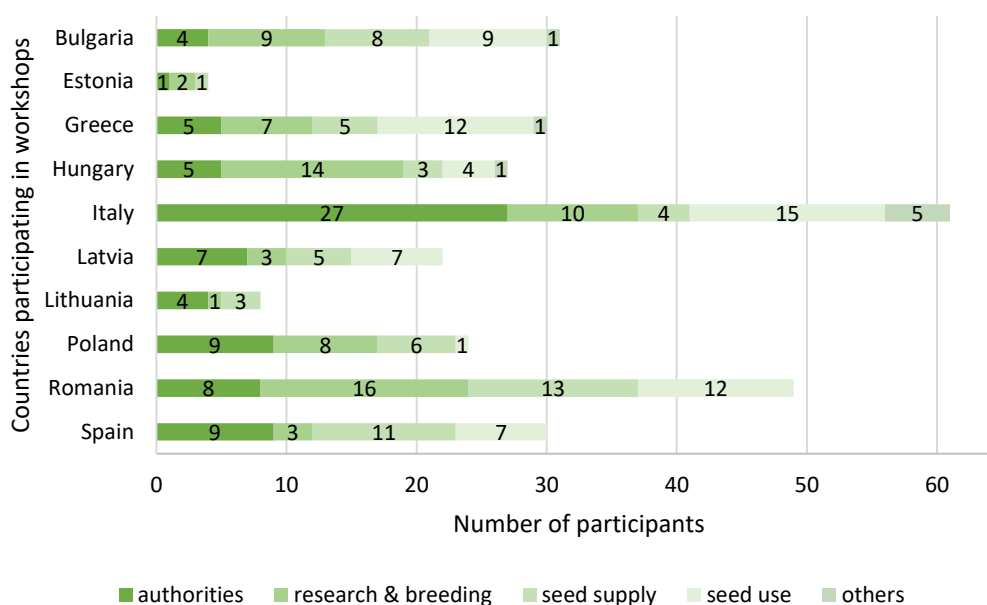


Figure 32 Number of participants per stakeholder group participating to the national workshops.

In all except one country (Italy), the workshop resulted in an organic seed declaration that was signed by all or most of the participants. The people that signed were, to a large extent, the people that had their name or organization linked to one of the action points in the declaration. Only in a few cases, people were hesitant to sign the declaration, possibly because they did not trust or understand the impact of it. Another reason for not signing was that some participants had already left the workshop at that point. Due to time limitations and the workshop setup, the participants of the Italian workshop did not sign their organic seed declaration. Nevertheless, the group discussion revealed several potential action points and commitments. To that effect, Italy was excluded from the quantitative but included in the qualitative analysis. The nine countries that signed the seed declaration made a total of 76 commitments (Figure 33). The progress report revealed that 34 out of 76 commitments (44.74%) have been fully implemented, and 29 out of 76 commitments (38.16%) have been partly implemented by the participants. Yet, for 13 out of 76 commitments (17.11%) no progress could be observed. Figure 3 illustrates how these values differ among countries. Hungary (87.50%) and Spain (66.67%) have the highest shares, whereas Latvia (26.67%) and Bulgaria (28.57%) have the lowest shares of fulfilled commitments (Figure 33). However, it should be noted that the number of commitments per country ranges from three (Lithuania) to 13 (Greece), as well as the complexity of each commitment.

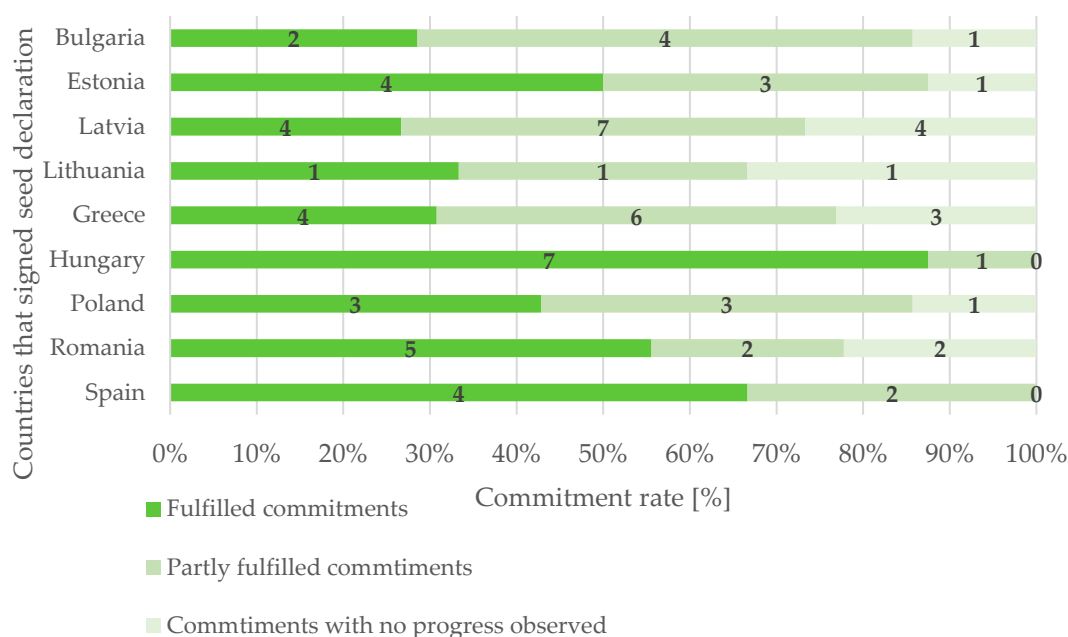


Figure 33 Number of commitments declared in the national organic seed declarations, and respective share of fulfilled commitments, partly fulfilled, and commitments with no progress observed as stated in the progress report.

Nevertheless, the high percentage of fulfilled commitments is a first indicator of a positive effect of the seed declaration on stakeholder involvement. It remains to be further

investigated whether the seed declaration is an effective tool that contributes to the development of the organic seed sector. For this, the quality of the commitments was analysed in greater detail. Table 17 summarises the commitments made in the national organic seed declarations. The table visualizes that all countries have committed to action points that correlate with category (iii), to increase information on varieties suitable for organic production. Additionally, this category contains the highest number of action points. In terms of content, the action points relate to research, training, and communication. This might be due to the fact that most of the research institutes and seed companies present at the workshops have the means to organize demonstration fields or field trials, unlike smaller farmer cooperatives. Hungary and Spain stand out from the rest of the countries in that they have only made commitments in two categories: (iii) increasing information on varieties suitable for organic production and (iv) increasing cooperation among the stakeholders. Table 17 further illustrates whether the wording of the commitment contains an active or passive verb; in other words, whether the stakeholders took over the responsibility themselves or handed over the responsibility to a third party. Examples of passive verbs are “propose”, “ask for”, or “request”; examples of active verbs are “organize”, “set up”, “start”, or “analyze”. Hungary is the only country that did not use passive verbs in its seed declaration. This might have contributed to the fact that Hungary reached the highest share of fulfilled commitments. The difference in wording becomes most evident in the category (i), improvements of national seed databases. Stakeholders either committed to suggesting improvements to the ministry, or stakeholders directly committed to improving the database—also because the responsible person was not present at the workshop.

This is illustrated by the examples below:

*The Tulcea farmers will send a letter to the Ministry of Agriculture and Rural Development in which they will suggest the possibilities for improvement of the database (LIVESEED Declaration of Organic Seed, Romania, 19 June 2019) (LIVESEED Reports, 2019).*

*K. R. from the Estonian Seed Association will cooperate with the Agricultural Board to improve the organic seed database (LIVESEED Declaration of Organic Seed, Latvia, 31 January 2019) (LIVESEED Reports, 2019).*

*E. S., on behalf of PIORIN, takes the initiative to analyze what is possible to improve in the database based on the recommendations, concerning its interactivity, user-friendliness [ . . . ] (LIVESEED Declaration of Organic Seed, Poland, 13 May 2019) (LIVESEED Reports, 2019).*

Table 17: Summary of commitments categorized according to the four key points on which the discussion was based. The verbs are highlighted to illustrate whether stakeholders took over the responsibility themselves (active verb) or handed over the responsibility

Country	(i) Improvements of National Seed Databases	(ii) Implementation of Incentives to Increase Production & Use of Organic Seed	(iii) Increase Information on Varieties Suitable for Organic Production	(iv) Increase Cooperation among the Stakeholders	(v) Other
Bulgaria	propose improvements of database or to return to organic seeds request to make derogation report public;	ask to fund registration of varieties suitable for organic production; ask to fund organic seed production & use	organize demonstration fields; collect and disseminate information on difference between organic and conventional seed	start social media group	/
Estonia	improve database	suggest support for the use of organic seed; ask to fund seed production equipment; include organic seed production & use in action plan	test varieties in organic field trials and disseminate of trial results; continue knowledge transfer program and organize information days	establish expert group	include varieties suitable for organic production in a breeding program
Greece	propose improvements of database; consider recommendations	put organic seed on meeting agenda	publish most recent derogation report; organize workshop on organic seed; set up course on organic seed production; put education & training on meeting agenda; discuss advantages of organic seed; disseminate information about advantages of organic seed; conduct farmer survey	activate scientific committee for organic farming; suggest organizing social media platform	get involved in organic seed production
Hungary	/	/	continue on-farm tests of varieties and landraces; process data collected on variety use and certification results; disseminate methodology; organize field day; launch farmer training; share information on EIP Agri portal; share summary of national workshop	coordinate consultation between seed producers	/

Country	(i) Improvements of National Seed Databases	(ii) Implementation of Incentives to Increase Production & Use of Organic Seed	(iii) Increase Information on Varieties Suitable for Organic Production	(iv) Increase Cooperation among the Stakeholders	(v) Other
Latvia	improve user-friendliness of database; include more information in database	raise criteria to apply for derogations; propose area-based subsidies for the use of organic seed; request support for the use of organic seed	test varieties in organic field trials; use support educational activities; carry out educational activities; ask for support of educational & research activities	expand functions and membership of expert group; participate in expert groups and express coherent opinion; promote cooperation in seed production and create EIP groups for research on seed production	strengthen control institutions
Lithuania	propose technical improvements of database		ask to develop organic production trainings; propose definition of "variety suitable for national organic production"	/	/
Poland	analyse how to improve database	inform about legislative barriers regarding organic plant breeding; monitor drafting process of action plan; suggest subsidies for farmers	conduct farmer survey; initiate educational activities and demonstrate advantages of organic seed	discuss the roles of an expert group	/
Romania	suggest improvements of database; inform about database existence		test varieties in organic field trials; organize meeting on organic seed; organize event on organic seed; offer support for soybean seed multiplication; offer technical support to organic farmers	involve stakeholders in debates regarding the implementation of new organic regulation; start social media group	/
Spain	/	/	analyse causes for derogations; improve dissemination on organic seed; share initiatives and successful results; compile info on benefits of using organic seed; gather information to develop organic seed for legumes	Request creation of a working group	/
Italy *	improve database	/	set up experiments to facilitate registration of varieties suitable for organic production	improve work of the expert group; ask for support in the discussion of delegated acts of the new organic regulation	/

The progress report revealed that in Poland, where the database manager herself took over the responsibility, improvements have been made regarding the functionality and update frequency of the database. The database now includes information on the amount of seed material offered by the seed supplier. However, seed producers are still not allowed to add and modify offers in the database. In contrast, in Estonia, the seed database is still an Excel file and requires considerable improvement to live up to the requirements of the New Organic Regulation EC 2018/848 (European Union, 2018). The progress that could be noted here was that organic seeds can be now found more easily in the general seed production database. In Romania, no progress could be observed. The Agriculture Ministry in Romania does not share the perception that a database can make a substantial change to increasing the production and use of organic seeds. This might indicate that the commitment is more likely to be fulfilled if the responsible person, in this case, the national authority, is included in the process of discussing, formulating, and signing the seed declaration. This is supported by the example of Italy, the only country where no official seed declaration was signed. Another peculiarity in the wording is that most commitments are clearly allocated to one responsible person or institution. Interestingly, the seed declaration in Spain was formulated in a more generalized way. This, however, did not seem to have a significant effect on the progress reported at the final LIVESEED stakeholder conference.

The difference in wording is illustrated by the examples below:

*We will organize two organic demonstration fields. Agricultural University in Plovdiv will provide fields, Vitalis will provide vegetable seeds. Bonevi Perfect will provide fields, Research Institute Sadovo will provide seeds for cereals. Bioselena will provide publicity for both field demonstrations (LIVESEED Declaration of Organic Seed, Bulgaria, 2 October 2019) (LIVESEED Reports, 2019).*

*Compile information on the benefits of using organic seeds to promote incentives for its use (LIVESEED Declaration of Organic Seed, Spain, 8 April 2019) (LIVESEED Reports, 2019).*

Furthermore, the complexity of the individual commitments varied greatly. For instance, some action points relate to sharing a methodology or starting a social media group, while other action points involve the organization of field trials, advocacy work, or the establishment of an organic seed expert group. Accordingly, in the latter cases, the completion of a task can take up to several years and, as a result, the commitment is declared as “partly fulfilled”. This exemplifies that a quantitative content analysis alone provides only limited information about the effectiveness of the seed declaration. The progress is ongoing and continuous progress monitoring is necessary to assess its effectiveness. In addition, the

monitoring has shown that progress does not only depend on the commitment of the stakeholders but can be hampered by unforeseeable external events. Notably, the pandemic caused by COVID-19 interfered with stakeholder meetings and educational activities. Other reasons for non-compliance were loss of contact persons, legislative restrictions, or lack of funding. Another aspect to consider is the limited comparability of countries. For instance, at the time of the national workshop, Italy and Latvia already had an established organic seed expert group. Both countries are committed to expanding the functions and membership of the expert group. Estonia committed to the more complex task of establishing an expert group for the first time. Not only the initial situation of a country is important, but also the resources that allow the stakeholders to follow up on the progress. It should be noted that Estonia and Lithuania did not participate in the LIVESEED project but were included in the joint workshop of the Baltic States. Despite their lack of co-financing, Estonia (50.00%) and Lithuania (33.33%) fulfilled a considerable number of their commitments. Lastly, at the final stakeholder conference, participants not only reported on committed actions but also on non-committed actions in favor of organic seed production and use. Additionally, further actors were involved in the fulfilment of the commitments. This could be due to a positive network effect in favor of organic seed production and use. In general, the progress report revealed positive developments compared to the years prior to the organic seed declaration. Project partners reported that the area of land used for growing organic seed crops is showing a clear increasing trend. This progress cannot be ascribed directly to the seed declaration, since the actions could have taken place without the seed declaration. Nevertheless, the results reveal that the seed declaration improved communication, created a shared sense of responsibility, and raised awareness on the matter of organic seeds. Participants showed a high motivation to commit to concrete action points for moving forward. Based on their feedback, they appreciated the national workshops as there have only been a few, if any, such events bringing together actors from all stakeholder groups to jointly discuss subjects related to organic seeds.

#### **4.4 Discussion**

The analysis indicates that the organic seed declaration, based on the concept of voluntary commitments, had a positive impact on stakeholder involvement. In addition, it could be shown that the process of discussing, formulating, and signing the seed declaration is essential to guaranteeing effectiveness. This is in line with (Böhringer & Frondel, 2022) who argue that progress monitoring is not enough to guarantee effectiveness. They state that commitments must be clear and demanding and should result from intensive mutual negotiations to create a sense of commitment among participants. The time between the national visits and the final

LIVESEED stakeholder conference was less than 2 years. The LIVESEED project provided funding, a platform, and facilitators. However, progress is ongoing and further in-person meetings are needed to create continuous opportunities for the exchange of experiences, challenges, and possibilities, facilitating a mutual learning process (Ramstein, 2012). It remains to be seen whether the stakeholders involved will remain committed and the progress will continue after the LIVESEED project. The area of land used for growing organic crops is showing a clear upward trend (Willer et al., 2023). However, it remains unclear if the area of organic seed multiplication is increasing at the same pace. To attribute a positive effect on the organic seed sector developments to our seed declaration, one would have to look at the efficiency. To this effect, the voluntary instrument should be compared to no interventions or to other instruments, for instance government-led mandatory approaches (Alberini & Segerson, 2002). To quantify efficiency in terms of costs or performance, a counterfactual reference scenario is needed that describes what would have happened in the absence of voluntary commitments. According to Böhringer & Frondel (Böhringer & Frondel, 2022), two counterfactual reference scenarios are proposed: The status-quo-conserving scenario assumes that the changes in the level of organic seed use result solely from voluntary commitments. This scenario overestimates the effects of the instrument, but it is often used when there is a lack of data. The business-as-usual or trend scenario considers developments of organic seed use that would have taken place even without the instrument, such as changing economic conditions. This scenario requires sufficient data prior to the policy instrument. Due to these difficulties, we have limited our analysis to effectiveness. However, we have achieved our goal of stimulating progress. The superiority of voluntary instruments lies in their cost- and time-efficiency (Brown Weiss, 2014). This means that voluntary commitments can respond to new problems more quickly and in a more flexible way compared to legislative negotiations that are often time-consuming and involve high transaction costs. According to Böhringer & Frondel (Böhringer & Frondel, 2022), a necessary condition for the effectiveness of voluntary commitments is the involvement of regulators in the intensive negotiations. However, this would reduce the cost- and time-efficiency of the instrument. Based on our results, we can equally conclude that if stakeholders from national authorities take over the responsibility themselves, for instance, to improve the organic seed database, the commitment is more likely to be fulfilled — thereby, improving efficiency in terms of performance. Even though voluntary commitments are increasingly used in environmental law and climate negotiations, to our knowledge there is no research that addresses efficiency. Examples from the agricultural sector show that voluntary commitments can take different forms. The authors of Smith et al. (Smith et al., 2019) assessed the effectiveness of voluntary sustainability standards in sugarcane production. Voluntary sustainability standards are a set of criteria that are developed with stakeholder involvement to promote sustainable production, and that are monitored by an independent certification system. Their analysis shows that

voluntary sustainability standards may be an effective tool to reduce negative environmental impacts, but there is limited understanding of economic and social costs. Equally, DeFries et al. (DeFries et al., 2017) evaluated different voluntary certification programs, such as Fair Trade, and their impact on the production of tropical agricultural commodities. They conclude that voluntary sustainability standards can have a positive effect on meeting sustainable development goals. However, they are often not enough to address economic and social outcomes for small-scale producers. To tackle the shortage of organic cultivars, Winter et al. (Winter, Grovermann, Aurbacher, et al., 2021) proposes a value chain partnership. As the entire value chain is affected by the shortage, the financing of organic breeding should also be borne by all stakeholders involved, rather than only by farmers and breeders, as it is often the case. Thus, in a so-called cross-sector funding strategy, the entire value chain commits to investing in organic breeding. This way the burden is distributed, and the entire value chain takes over the responsibility. Their conclusion is based on an extensive stakeholder dialogue in which many interviewees indicated the necessity of committing the entire value chain. However, Winter et al. (Winter, Grovermann, Aurbacher, et al., 2021) also addressed the problem of the voluntary nature of the strategy: “as long as there are no binding agreements between the actors to invest, they may prefer to maximize their short-term interests. The awareness-raising and communication element of the pool funding strategy is a crucial framework condition to mitigate this risk”. While this example is theoretical, Winter et al. (Winter, Grovermann, Aurbacher, et al., 2021) refers to some existing examples. One example is the Fair Breeding® initiative, a small-scale value chain partnership in Germany. The initiative was launched by Kultursaat and Naturata International in 2007 with the objective of involving value chain actors in cultivar development and conservation. Over a period of 10 years, value chain actors committed to channeling a small share of their revenue into organic vegetable breeding. Through this partnership, three open-pollinating cauliflower cultivars have been brought to variety registration and release (Fuss et al., 2020). By increasing organic breeding activities, both examples of Winter et al. (Winter, Grovermann, Aurbacher, et al., 2021) can indirectly and positively affect organic seed supply, but this does not directly relate to the target of the organic regulation to use 100% organic seed by 2036. The results of this paper support the important role of the concept of organic seed expert groups (Fuss et al., 2020). Organic seed expert groups consist of stakeholders involved in the organic seed supply chain. National organic seed expert groups have the mandate to advise their national competent authority on implementing the regulation on organic seed in the country. At present, 11 EU member states (mainly Central and Northern European countries) have implemented such organic seed expert groups (Fuss et al., 2020). While expert groups differ in terms of implementation between countries, these groups can provide the framework for getting to intensive mutual negotiations, as requested by Böhringer & Frondel (Böhringer & Frondel, 2022). Looking at the commitments in this paper, we find that six out of ten countries

(Estonia, Latvia, Poland, Romania, Spain, and Italy) committed to either establishing a seed expert group, expanding the functions and membership of expert groups, discussing the role of an expert group, involving stakeholders in debates regarding the implementation of new organic regulation, or requesting the creation of a working group or improving the work of the expert group. These theoretical and practical examples show that voluntary commitments can have positive effects. Due to the diverse nature of these voluntary commitments, it is difficult to compare instruments and draw a general conclusion. Government-led mandatory approaches might be needed to reach sustainability goals. However, as long as the European Commission shows a high degree of political uncertainty and reluctance—as illustrated by Raaijmakers & Schäfer (Raaijmakers & Schäfer, 2019)—voluntary commitments will play an important role in the future.

## 4.5 Conclusions

In this paper, we have discussed the effectiveness of the organic seed declaration based on the concept of voluntary commitments. Our aim was to gain stakeholder involvement and active participation to jointly foster the development of the organic seed sector in the 10 selected countries. The presented results demonstrate that the organic seed declaration was successful in engaging and connecting stakeholders, and in instilling a sense of commitment to a common goal. Coinciding with our organic seed declaration, positive developments were observed in the organic seed market. Through qualitative methods of analysis, we addressed how the wording of action points in the covenant can influence the degree to which they are fulfilled. This revealed that, despite positive network effects, all stakeholders, especially authorities, should be included in the process of discussing, formulating, and signing the seed declaration. Practical and theoretical examples from the agricultural sector show that voluntary commitments can be applied in various forms and have a positive impact. Despite these positive results, and in order to take into account any limitations of this instrument, it is important to communicate voluntary commitments as a complementary tool to mandatory policy instruments. To reach the aim of 100% organic PRM, European and national authorities should not rely on voluntary commitments through stakeholder involvement alone, but should address existing political obstacles and bottlenecks. A mixture of instruments—voluntary and mandatory policy instruments—may be needed to reach the goal of 100% organic PRM in the EU by 2036. To conclude, the voluntary organic seed declarations have made the first steps in the right direction. The question now is whether the progress will continue without the funding provided by the LIVESEED project; for instance, if the newly established seed expert groups and other built-up structures will remain in place and continue to function. It will be necessary to continue progress monitoring to keep the shared sense of responsibility alive. Further workshops promoting the national and transnational exchange of information are needed to harmonize the implementation of the rules

for organic PRM in the new European regulation (EU) 2018/848 (European Union, 2018).

### **Author Contributions**

Conceptualization: Freya Schäfer and Maaïke Raaijmakers; Data curation: Freya Schäfer, Maaïke Raaijmakers, Katharina Meyer, Xenia Gatzert, Martin Sommer and Ágnes Bruszik; Funding acquisition: Monika Messmer; Methodology: Freya Schäfer; Project administration: Freya Schäfer; Supervision: Monika Messmer; Writing – original draft: Freya Schäfer and Kaja Gutzen; Writing – review & editing, Freya Schäfer, Kaja Gutzen, Maaïke Raaijmakers, Katharina Meyer, Xenia Gatzert, Martin Sommer, Ágnes Bruszik and Monika Messmer. All authors have read and agreed to the published version of the manuscript.

## 5. Overall Discussion

Since the last decade there was little scientific literature available on the context of the organic seed and breeding sector in Europe. In 2012, Döring et al. (Döring et al., 2012) published a relevant paper on the organic seed regulations framework in Europe and the current status and recommendations for future. With the support of the LIVESEED project from 2017 onwards several peer reviewed papers could be published. The three papers presented in this thesis add up as relevant milestones in better understanding the context of the organic seed and breeding sector in Europe.

Expanding organic seed and breeding activities faces several barriers from the perspective of seed suppliers and breeders. The first research question of this thesis – **“What barriers exist to expand organic seed and breeding activities from the seed suppliers’ and breeders’ perspective?”** – reveals distinct findings (Chapter 2, page 18ff). Overall, the identified perspectives across Europe do not show significant regional patterns. The research of this thesis shows that actors identifying themselves with “a strong focus on organic and participatory breeding for diversity”, revealing from factor B-I of the principal factor analysis in Chapter 2 from page 28 onwards, cannot be linked to a certain region within Europe. This results can be supported by the regional distribution of members from the European Consortium for Organic Plant Breeding (ECO-PB) as the organisation is represented by Members from 15 different European countries across Europe (ECO-PB, 2025). Thus, it can be assumed that the concept of “organic breeding” may have become established across Europe. However, the research in this thesis indicates that these breeding initiatives need to deal with a very low yearly turnover. They face significant financial challenges which may limit potential investments to expand their breeding activities. Though it is questionable if the concept of organic breeding will be able to deliver a broad range of adapted varieties for the whole organic farming sector within Europe. Organic and participatory breeding may enhance genetic diversity, resilience, and adaptability to organic farming conditions (Joshi et al., 2023; Legzdina et al., 2022; Serpolay-Besson et al., 2014), but without a robust business concept breeding effort may lag behind its potential (Hiester, 2025). Kotschi et al. (Kotschi et al., 2022) describe traditional financing through intellectual property rights, also known as “seed royalties”, as unsuitable funding source for organic variety development, as it conflicts with the organic principle of treating seed as a common. However, in the realm of organic breeding, different approaches are employed by various actors (Winter, Grovermann, Aurbacher, et al., 2021). Some organic breeders, particularly those focused on cereal crops, opt for traditional methods of variety protection and registration (Grovermann et al., 2022). This approach allows them to maintain control over their developed varieties and potentially commercialize them. On the other hand, there are organic breeders who work with open-pollinated cultivars. These breeders often take a different route, relying on what are known as amateur

varieties. This approach typically involves less formal registration processes and may prioritize genetic diversity and adaptability over standardization (Osman & Chable, 2007). These contrasting strategies within organic breeding reflect the diverse goals and philosophies within the field. While some aim for more standardized and protected varieties, others focus on maintaining genetic diversity and promoting adaptable, locally-suited crops. The need to improve transparency and a “level playing field” is a relevant factor Europe-wide, as indicated by the results of Chapter 2 from page 28 onwards. Solfanelli et al. (Solfanelli, Ozturk, Dudinskaya, et al., 2022) report that there is a significant lack of comprehensive and comparable data on organic seed production and use across Europe. This data gap hinders the development of the organic seed market, as current reports are often basic and inconsistent across different regions and periods (Solfanelli, Ozturk, Dudinskaya, et al., 2022). Padel et al. (Padel et al., 2021) argue that a lack of seed availability and pricing information further complicates market dynamics. The research in this thesis indicates that the organic seed market is small, diverse, and fragmented, especially larger companies that face organizational or technical challenges, as indicated in the results of Chapter 2 from page 28 onwards. Maintaining high standards of seed quality, hygiene, and vigour is a significant challenge (Klaedtke et al., 2022; Nyochembeng, 2021). Organic seeds often face higher risks of contamination from weed seeds and seed-borne diseases compared to conventional seeds (Kim et al., 2022; Kolašinac et al., 2018; Nyochembeng, 2021; Wood, 2003). Effective disease management strategies, such as early harvest and natural seed treatments, are crucial but challenging to implement consistently (Kolašinac et al., 2018; Wood, 2003). Trade incompatibilities may hinder the growth of the organic seed sector. The lack of decisive guidance on organic seed regulations leads to divergent practices that do not meet the sector's needs (Renaud, 2014). However, the research also indicates that some actors have trust in the development of the organic seed sector in Europe and that it will become profitable in the future (Solfanelli et al., 2021).

The analysis of trends in the use of crop cultivars from both organic and conventional seed multiplication in Germany (see Chapter 3, pages 44ff) indicates that the organic cereal seed sector is a growing market. This growth is evidenced by an increase in cultivars derived from organic multiplication recorded in the national seed database. The analysis reveals that this database effectively displays changes in the supply and adoption of organic seed. Farmers appear to respond to the offerings in the national database, using it as a source of information; consequently, the use of non-organic cereal seed has been declining over time. Annual fluctuations in the availability of organic cereal seed and corresponding shortages in organic seed supply may be attributed to adverse weather conditions or other agronomic factors. This is reflected in the rising number of derogation requests for non-organic seed after a drop of organic seed supply. Addressing the second research question – **“Can the implementation of national seed provisions and policy measures promote the supply and uptake of organic seed and planting**

**material?”** – the findings reveal that a computerised organic seed database, as analysed in Germany (OrganicXseeds, 2025), effectively reflects the current market situation, thereby supporting transparency in the seed sector. Creating a “level playing field” in organic seed production is essential to ensure fair competition and accessibility within the organic seed market. This is vital for enhancing the competitiveness of organic agriculture and encouraging farmers to use organic seeds. My research indicates that the organic seed sector for agricultural crops is developing in Germany; however, the supply of organic horticultural crops still lags behind its potential. The findings suggest that an increased supply of agricultural organic seeds, as indicated in the national organic seed database, correlates with a decrease in the usage of non-organic seeds, as farmers are obligated to use organic materials when available. Since the listing of available organic seeds in national organic seed databases is voluntary, seed suppliers may wonder if the associated administrative work is worthwhile (Raaijmakers & Schäfer, 2019). A well-functioning real-time database, like the analysed German national organic seed database (OrganicXseeds, 2025), can enhance the visibility and transparency of organic seed offers and significantly reduce the use of non-organic seeds. The data analysis of the OrganicXseeds.de database in Chapter 3 represents the first peer-reviewed publication analysing a national organic seed database. The work conducted in co-authorship in Solfanelli et al. (Solfanelli, Ozturk, Orsini, et al., 2022) provides an overview on the implementation of national organic seed databases across Europe and how functionality could be improved.

Engaging stakeholders through voluntary commitments and action points decisively cultivates a collaborative environment essential for enhancing organic seed supply. An analysis of commitments from ten EU member states (see Chapter 4, page 70ff) reveals significant efforts to improve governance at the national level. These commitments, ranging from the enhancement of national seed databases to the provision of crucial information on varieties suitable for organic production, clearly demonstrate the capacity to increase transparency and accountability within the organic seed sector. Research conducted across these ten EU member states confirms that adopting a multi-actor approach is effective in stimulating stakeholder involvement and fostering a unified sense of purpose. Organic seed expert groups, existing in several EU member states (Fuss et al., 2020), play a critical role in this engagement. Notably, six out of the ten member states have committed to either establishing new seed expert groups or expanding the functions and membership of their current groups. The formulation of national seed provisions, including pre-ordering rules and classifications of crops or sub-groups of crops into category I lists (European Union, 2018) coupled with policy measures and incentives, is vital in promoting the uptake and production of organic seed and planting material. Organic seed expert groups are well-positioned to offer valuable guidance on the establishment of these seed provisions and related incentives and policies. The EU LEADER program serves as a prime example of where local stakeholders actively collaborate toward a shared goal (Dax & Oedl-Wieser, 2016).

Osti (Osti, 2000) asserts that the decision-making process within the EU LEADER program must adhere to the twin principles of subsidiarity and partnerships. The subsidiarity principle empowers decision-making by bodies positioned as close as possible to areas of intervention, while the partnership principle ensures inclusive negotiations among all relevant entities at a balanced level (Osti, 2000). LEADER's main impact is seen in “providing learning processes in rural regions and affecting changes in local governance through extended involvement of local stakeholders and institutions” (Dax & Oedl-Wieser, 2016). Bourget (Bourget, 2019) emphasizes that the European Commission’s framework for 2021-2027 allows each EU member state to craft a comprehensive strategic CAP (European Union, 2021) plan tailored to its unique needs, thus fostering an environment conducive to advancing the organic seed and breeding sector in Europe. To tackle the question, — **“Are there overarching criteria that improve governance of the organic seed and breeding sector within the organic farming regulation 2018/848?”** — the work of Porter and Ronit (Porter & Ronit, 2011) is considered, as it made valuable contributions by critically examining the changing dynamics of global business authority and its implications for democracy and governance. This analysis reveals that global business authority has the potential to significantly enhance transparency, accountability, and participation in governance structures. These principles were integral to the developmental discourse of the 1990s (Carothers & Brechenmacher, 2014). Applying these principles to the organic seed sector in Europe, transparency can be unequivocally enhanced by implementing robust, real-time national organic seed databases (Schäfer et al., 2024; Solfanelli, Ozturk, Orsini, et al., 2022) and effectively collecting and analysing data on the supply and demand for organic seeds and planting materials (Solfanelli, Ozturk, Dudinskaya, et al., 2022). Accountability must be enforced through public access to derogation regimes and processes, the publication of national derogation reports, and the clear classification of crops and sub-groups of crops into derogation categories (European Router Database, 2024). Moreover, a reliable and supportive policy framework is imperative to drive investments in the organic seed sector. Upholding accountability in organic agriculture is not negotiable; it is essential to maintain the integrity and credibility of organic production systems. A top-down approach with one common Europe-wide end date to phase out the use of non-organic seed in organic farming should be avoided as it often overlooks local barriers, leading to unrealistic targets and a disconnection between policymakers and implementers. In the worst case, it could lead to a situation where certain crops (especially in the vegetable and fruit sector) could no longer be grown organically. The absence of key stakeholder involvement, particularly from supply chain actors in policy formation and implementation, frequently results in poorly targeted policies. To achieve participation, it is essential to leverage the involvement of stakeholders through national or international organic seed expert groups (Fuss et al., 2020) and multi-actor projects such as LIVESEED (LIVESEED, 2017), LIVESEEDING (LIVESEEDING, 2022), and ROADMAPS (ROADMAPS, 2023). This proactive

engagement can be crucial for the successful advancement of the organic seed sector.

## 5.1 Methodological Reflections

The research in this thesis draws a strong link to social science and just to some extent to agronomical research. By providing descriptive information and facilitating the identification, diffusion, and adoption of new technologies, social sciences can support the development of appropriate policies and monitoring of ongoing projects (DeWalt, 1988). The principal (axis) factor analysis (PFA), applied in Chapter 2 of this thesis is a statistical method used to explain the correlations among observed variables by identifying a smaller set of underlying factors. This technique is closely related to principal component analysis (PCA). PFA aims to explain the correlations between observed variables by identifying underlying factors that account for the shared variance among these variables. This method is particularly useful for understanding the structure of interrelationships between variables (Bennett & Bowers, 1976; Wang, 2009). For instance, in better understanding factors influencing farmers' adoption of organic farming (Sapbamrer & Thammachai, 2021) or identify value orientations as determinants of preference for external and anonymous whistleblowing (Nayir & Herzig, 2012). PCA is used to reduce the dimensionality of a dataset by transforming the original variables into a new set of uncorrelated variables called principal components (Wang, 2009). These components capture the maximum variance in the data and is widely used in ecology for instance to compare the influence of land use and farming systems on soil microbial diversity (Lori et al., 2022; Thoms et al., 2010). The research conducted in Chapter 3 on trends in use of crop cultivars from organic and conventional multiplication in Germany is based on correlation analysis between the numbers of cultivars available from organic multiplication and the number of cultivars from non-organic multiplication requested via derogations. However, the number of cultivars available to organic farmers does not reflect if available cultivars are well suited to the farmers individual production conditions. As national organic seed databases don't record the quantitative volumes of organic seed and cultivars being available, the analysis in Chapter 3 focuses on the overall changes in cultivar assortment for 17 individual crop species in Germany. The work conducted in Chapter 4 constitutes more a conceptual framework on how fostering stakeholder involvement rather than empirical work. By integrating aspects of human behaviour, social structures, and cultural contexts into research, the implementation and adoption of agricultural innovations can be improved.

## **5.2 Limitations**

The research conducted in the thesis faces methodological limitations, such as limitations in sample size and composition, in a lack of available or reliable data and a lack of prior research on the topic. Research process limitations, such as time constraints, limited access to information or participants, budget restrictions and researcher bias or inexperience may occur just to a limited extent. Thus, the specific results of this thesis cannot be generalised but at a meta level may contribute to making transparent the level of diversity and complexity of aspects associated with the organic seed and breeding sector in Europe.

## **6. Conclusions & Outlook**

The research provides a small glimpse on the whole picture of realities and perspectives of actors in the organic seed and breeding sector in Europe. The organic seed and plant breeding sector in Europe is diverse and faces numerous challenges and opportunities. This diversity is influenced by various factors, including geographical, economic, and policy-related aspect. European regulations mandate the use of organic seeds, but due to insufficient supply, derogations allowing the use of non-organic seeds are still common. This reliance on derogations can impede investment in organic seed production and breeding, potentially affecting future supply of suitable seed and cultivars. Involving actors in the organic seed sector requires a multifaceted approach that includes stakeholder commitment, innovative financing models, and addressing market challenges. Collaborative efforts, such as participatory breeding and cross-sector funding, are essential to overcoming obstacles and ensuring the sustainable development of the organic seed sector. Continued monitoring and adaptation to changing dynamics are crucial for maintaining progress and achieving long-term goals.

### **6.1 Future Research Directions**

Within the Horizon Europe LIVESEEDING project, the succeeding project of LIVESEED, I am coordinating the work package on “Increasing the transparency in the organic seed sector”. The work package focuses on stakeholder dialogues, capacity building for national and regional authorities, improving the functionalities of the EU Router database [www.seeds4organic.eu](http://www.seeds4organic.eu), and analyse the status quo on supply and demand of organic seed and planting material. This analysis will feed into the report of the European Commission to the European Parliament on the possibility to phase out non-organic seed use by end of 2036 (LIVESEEDING, 2022).

Within the BÖL project ROADMAPS, funded by the Ministry of Agriculture in Germany, I am coordinating a multi-actor approach concept to gather information

and perspectives on the organic seed and breeding sector in Germany (ROADMAPS, 2023). The research focuses on the possibility to phase out derogations on non-organic seeds and planting material for horticultural and agricultural crops as well as for vegetative planting material. The project aims to collect statistical data as well as individual knowledge that is not documented: This knowledge, which is often referred to as "tribal knowledge" can add relevant information in better understanding crop and business-related contexts.

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# APPENDIX A

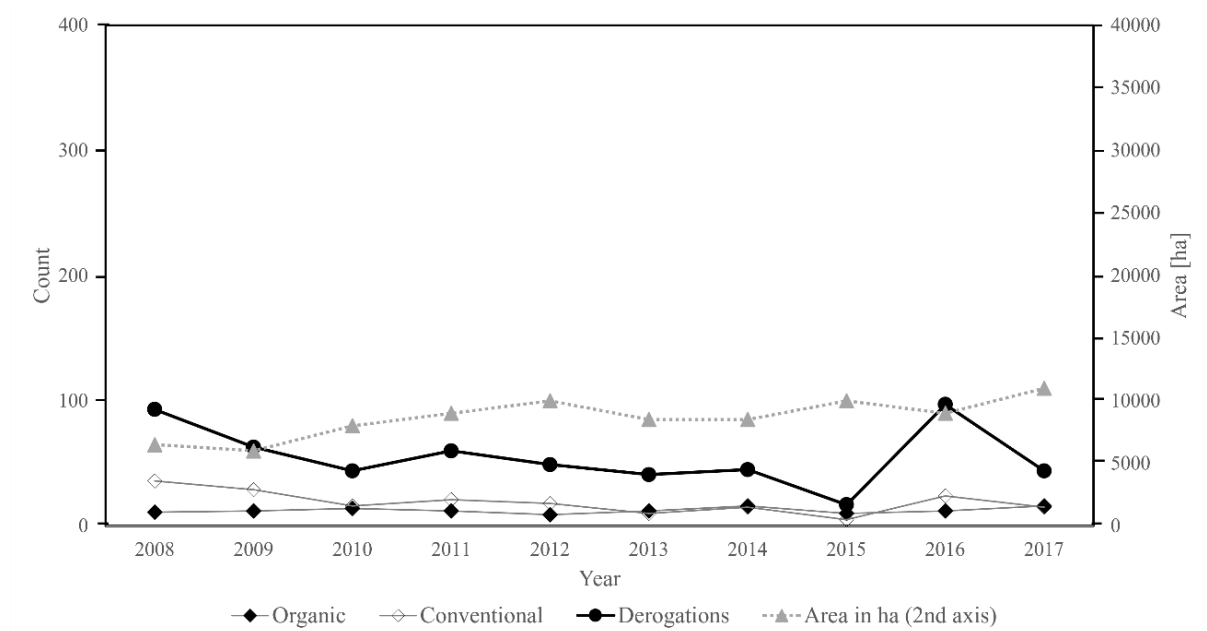


Figure A 1 An overview of spring wheat  
 Note: The left axis displays changes in supply of cultivars from organic multiplication (Organic), changes in cultivars requested from conventional multiplication (Conventional), and the number of derogations requested per year (Derogations). The right axis displays the corresponding organic crop area (Acreage) in hectares per year in Germany.

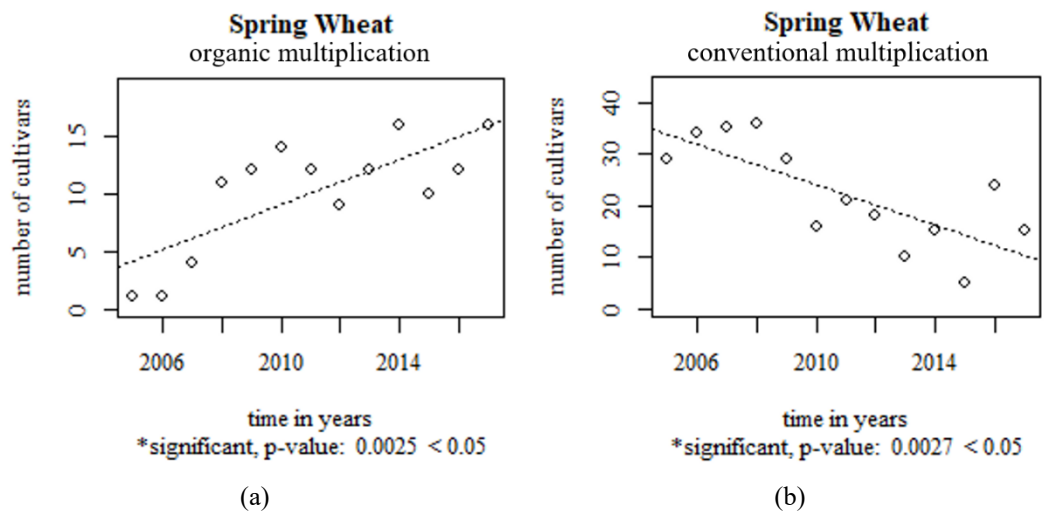


Figure A 2 Scatter plots with regression lines for spring wheat during 2005-2017 (a) the number of cultivars available from organic multiplication; (b) the number of cultivars requested from conventional multiplication

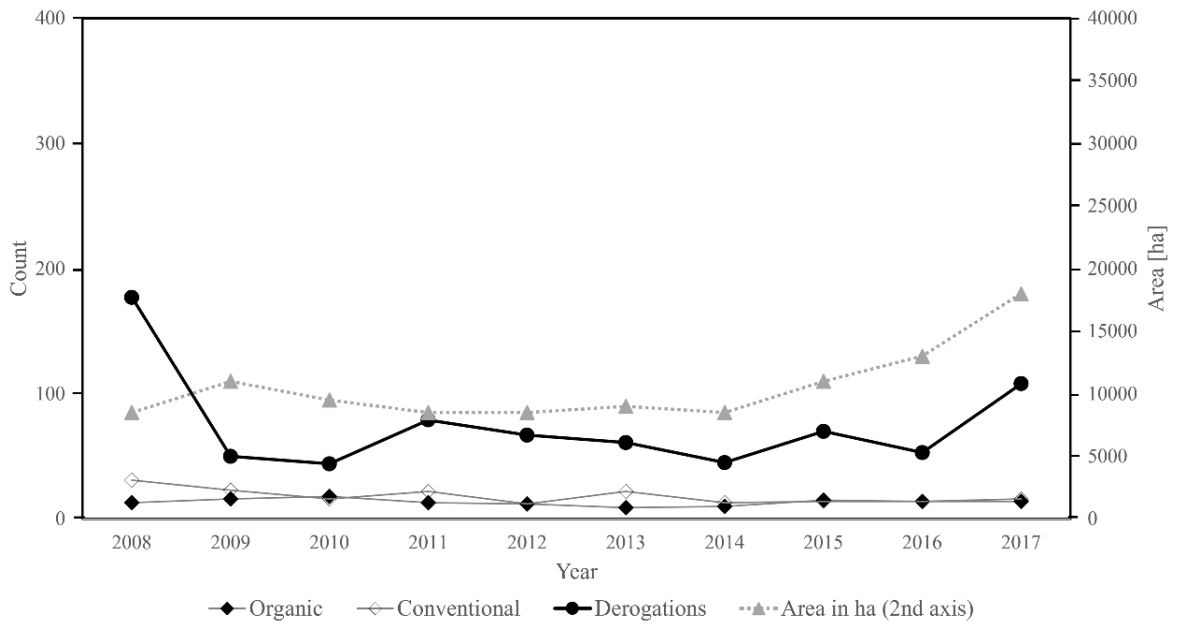


Figure A 3 An overview of winter barley  
 Note: The left axis displays changes in supply of cultivars from organic multiplication (Organic), changes in cultivars requested from conventional multiplication (Conventional), and the number of derogations requested per year (Derogations). The right axis displays the corresponding organic crop area (Acreage) in hectares per year in Germany.

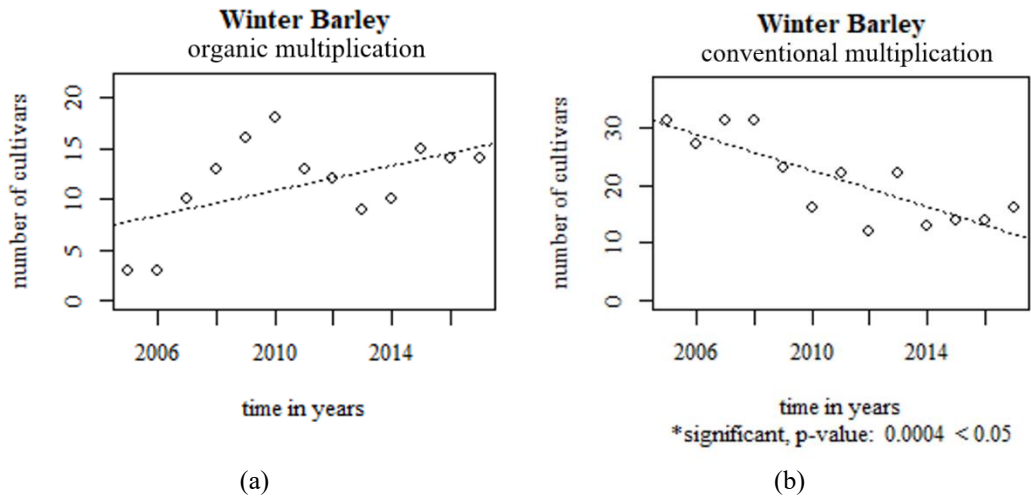


Figure A 4 Scatter plots with regression lines for winter barley during 2005-2017 (a) the number of cultivars available from organic multiplication; (b) the number of cultivars requested from conventional multiplication

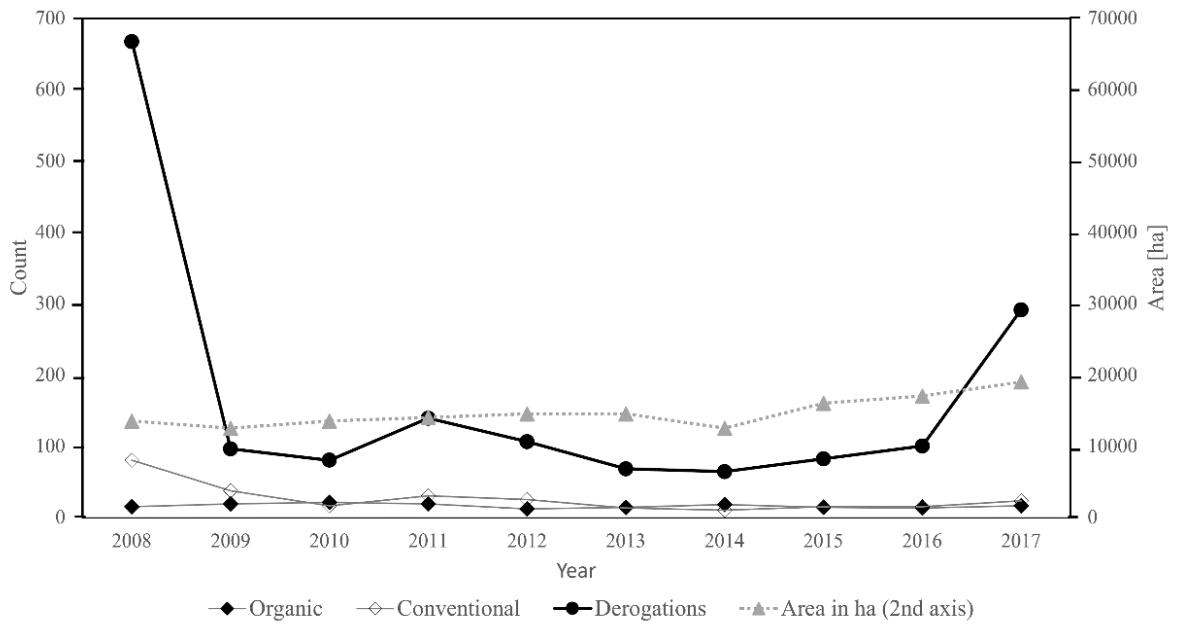


Figure A 5 An overview of spring barley

Note: The left axis displays changes in supply of cultivars from organic multiplication (Organic), changes in cultivars requested from conventional multiplication (Conventional), and the number of derogations requested per year (Derogations). The right axis displays the corresponding organic crop area (Acreage) in hectares per year in Germany.

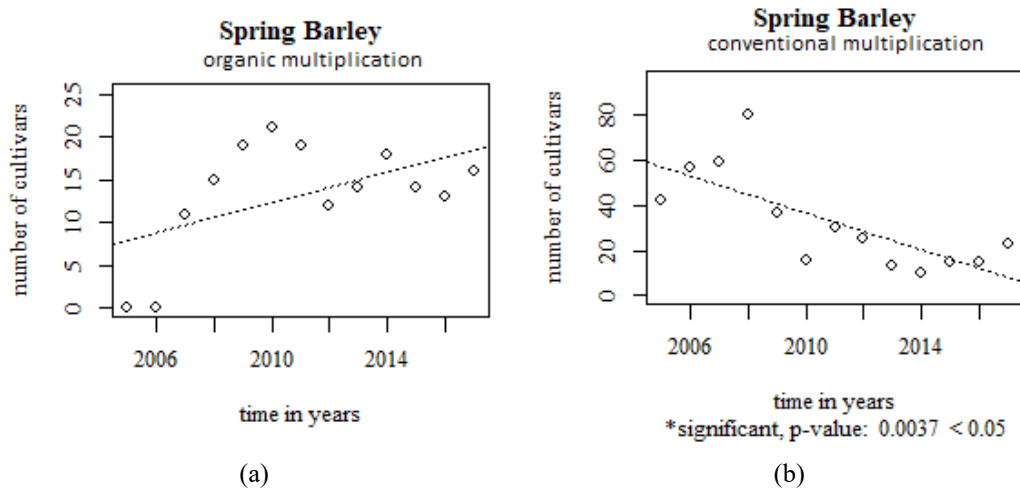


Figure A 6 Scatter plots with regression lines for spring barley during 2005-2017 (a) the number of cultivars available from organic multiplication; (b) the number of cultivars requested from conventional multiplication

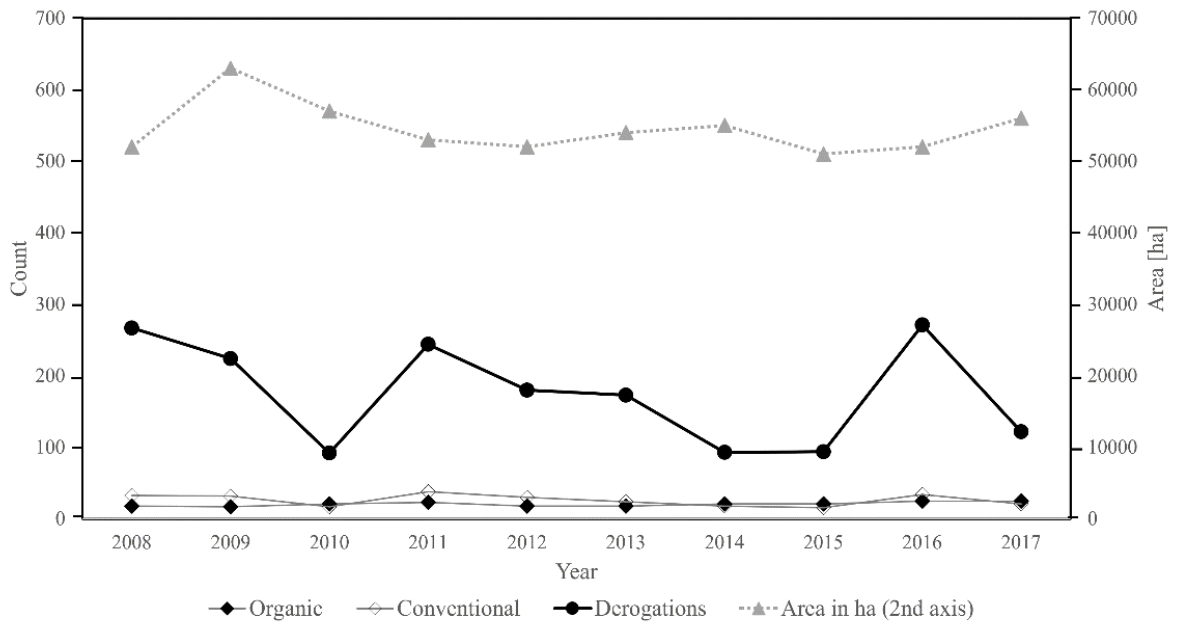


Figure A 7 An overview of rye

Note: The left axis displays changes in supply of cultivars from organic multiplication (Organic), changes in cultivars requested from conventional multiplication (Conventional), and the number of derogations requested per year (Derogations). The right axis displays the corresponding organic crop area (Acreage) in hectares per year in Germany.

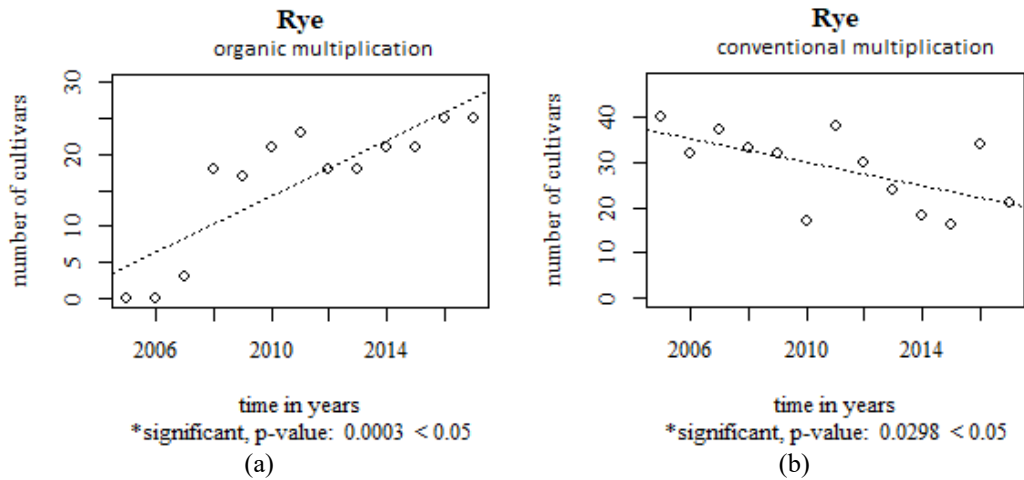


Figure A 8 Scatter plots with regression lines for rye during 2005-2017 (a) the number of cultivars available from organic multiplication; (b) the number of cultivars requested from conventional multiplication

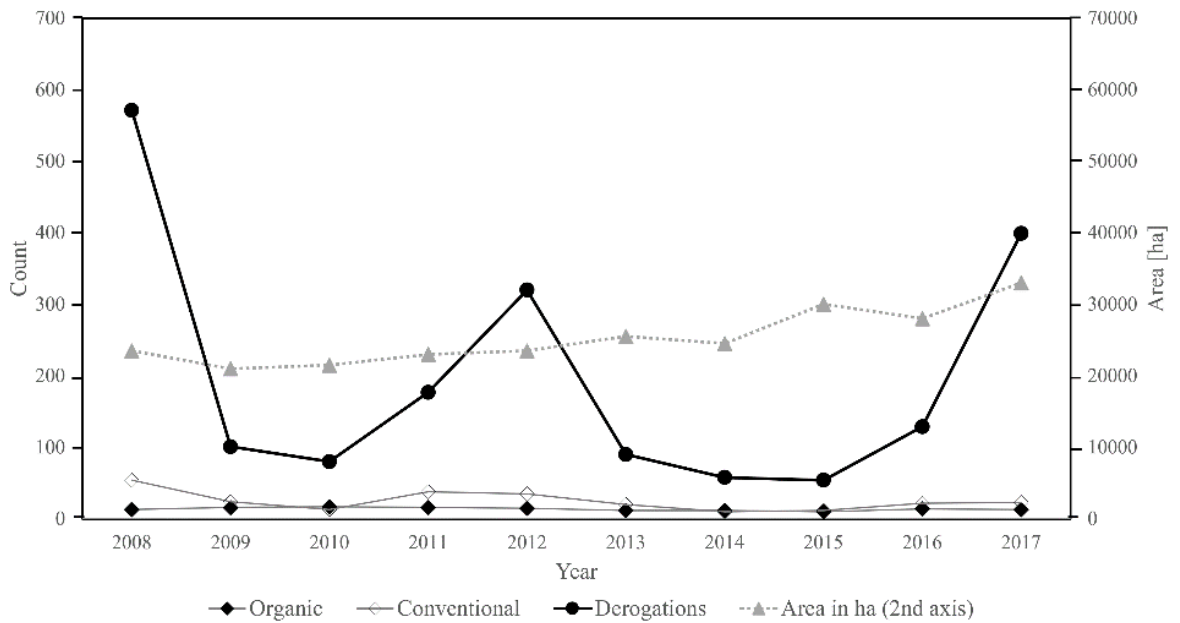


Figure A 9 An overview of oat

Note: The left axis displays changes in supply of cultivars from organic multiplication (Organic), changes in cultivars requested from conventional multiplication (Conventional), and the number of derogations requested per year (Derogations). The right axis displays the corresponding organic crop area (Acreage) in hectares per year in Germany.

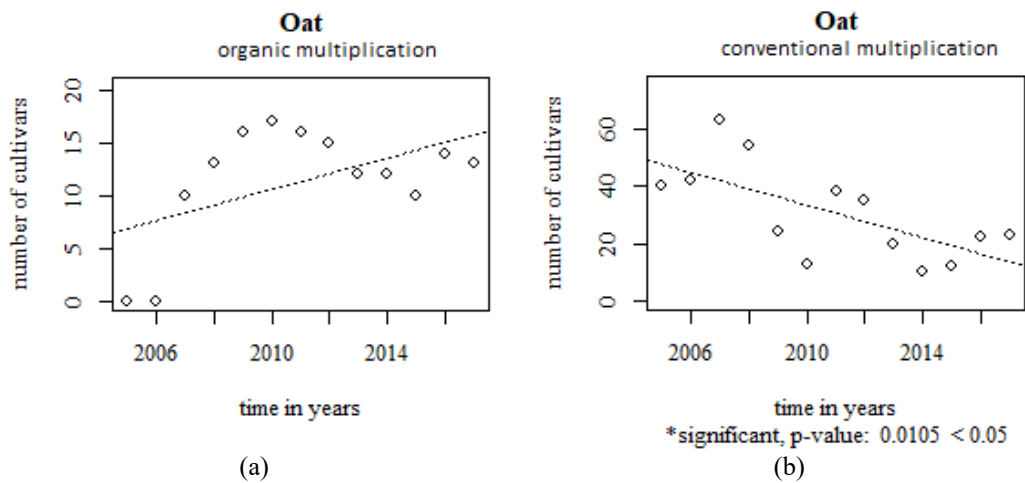


Figure A 10 Scatter plots with regression lines for oat during 2005-2017 (a) the number of cultivars available from organic multiplication; (b) the number of cultivars requested from conventional multiplication

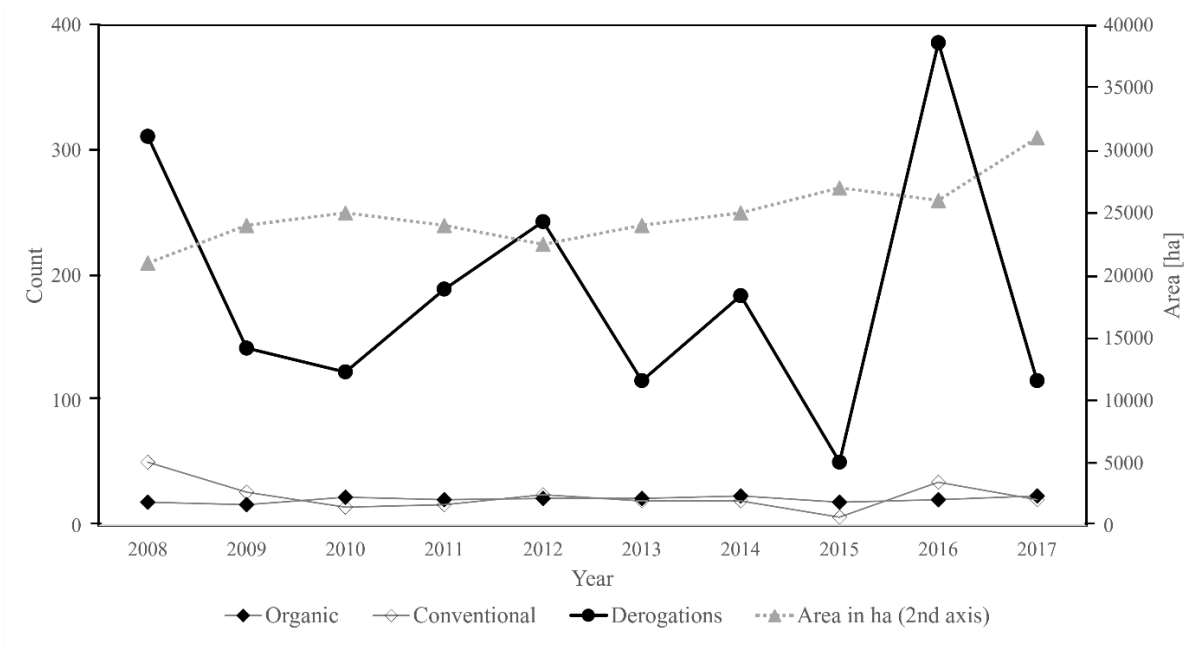


Figure A 11 An overview of triticale

Note: The left axis displays changes in supply of cultivars from organic multiplication (Organic), changes in cultivars requested from conventional multiplication (Conventional), and the number of derogations requested per year (Derogations). The right axis displays the corresponding organic crop area (Acreage) in hectares per year in Germany.

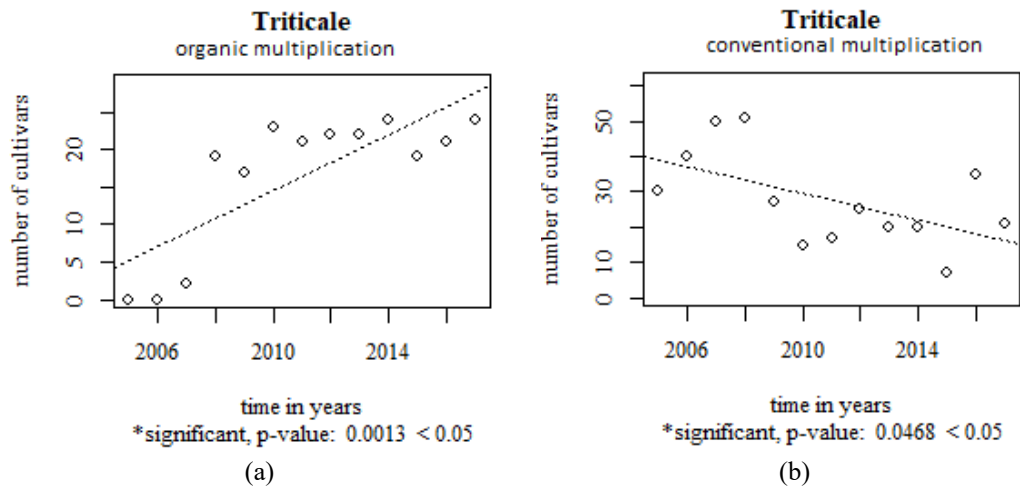


Figure A 12 Scatter plots with regression lines for triticale during 2005-2017 (a) the number of cultivars available from organic multiplication; (b) the number of cultivars requested from conventional multiplication

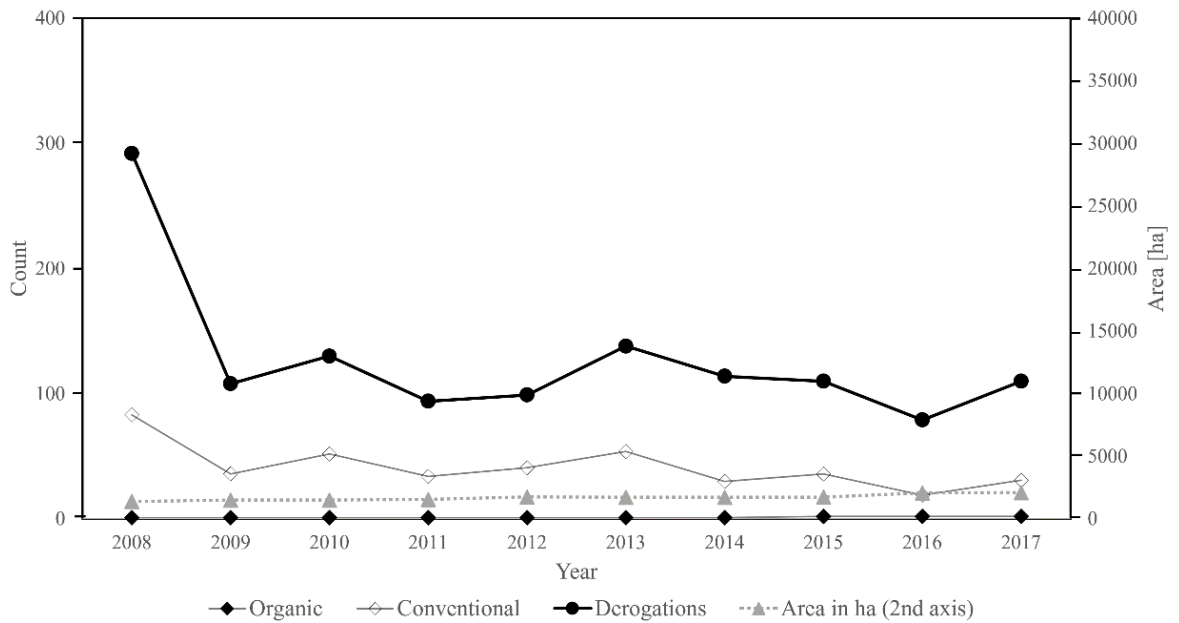


Figure A 13 An overview of carrot

Note: The left axis displays changes in supply of cultivars from organic multiplication (Organic), changes in cultivars requested from conventional multiplication (Conventional), and the number of derogations requested per year (Derogations). The right axis displays the corresponding organic crop area (Acreage) in hectares per year in Germany.

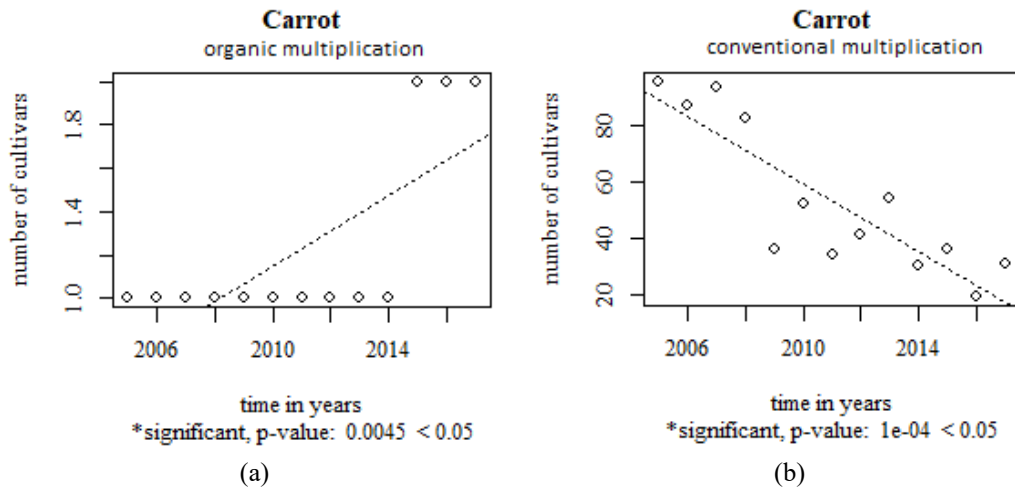


Figure A 14 Scatter plots with regression lines for carrot during 2005-2017 (a) the number of cultivars available from organic multiplication; (b) the number of cultivars requested from conventional multiplication

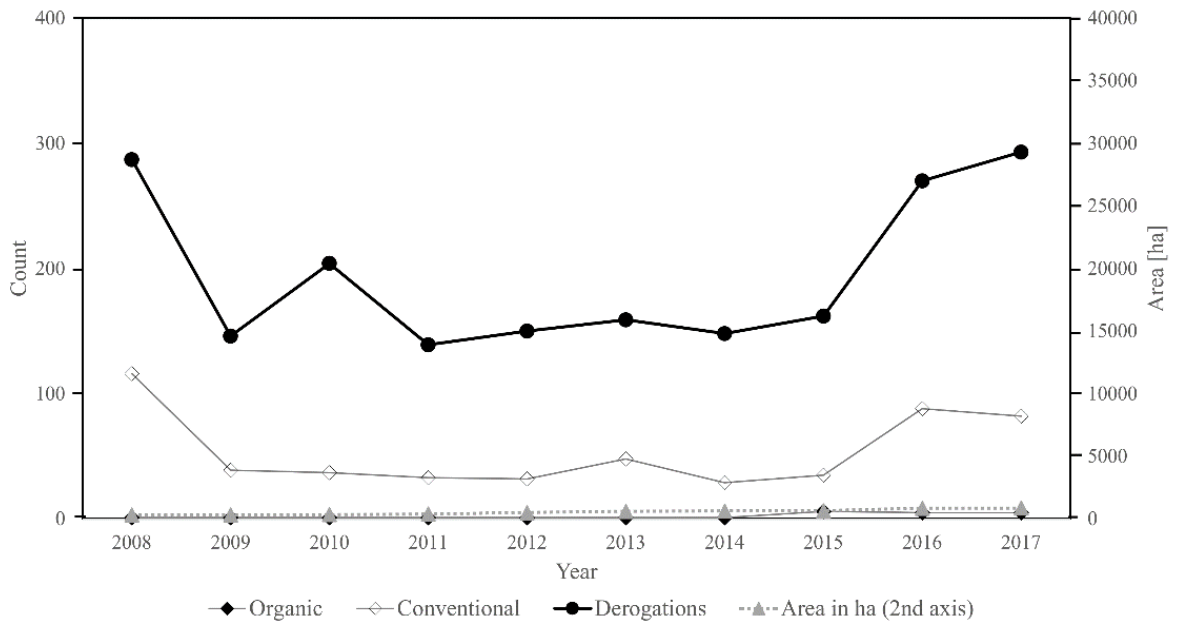


Figure A 15 An overview of onion

Note: The left axis displays changes in supply of cultivars from organic multiplication (Organic), changes in cultivars requested from conventional multiplication (Conventional), and the number of derogations requested per year (Derogations). The right axis displays the corresponding organic crop area (Acreage) in hectares per year in Germany.

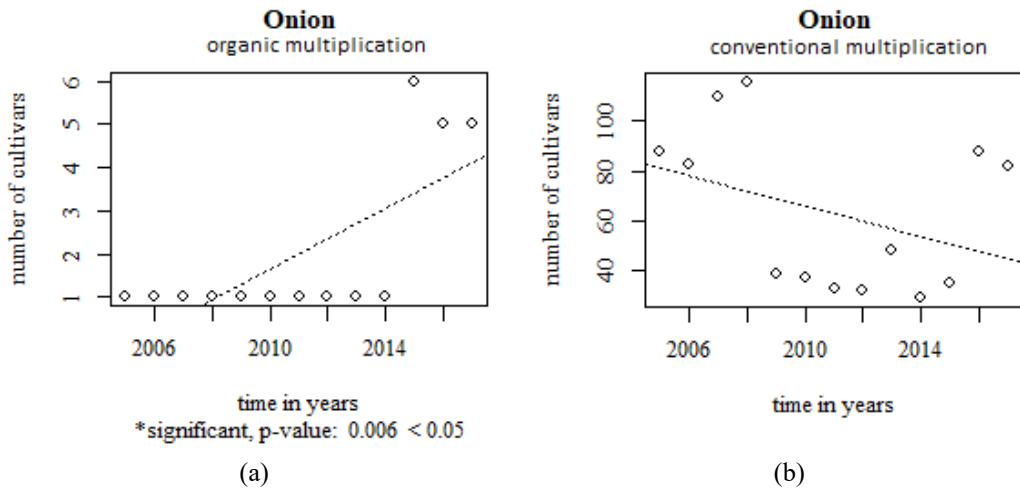


Figure A 16 Scatter plots with regression lines for onion during 2005-2017 (a) the number of cultivars available from organic multiplication; (b) the number of cultivars requested from conventional multiplication

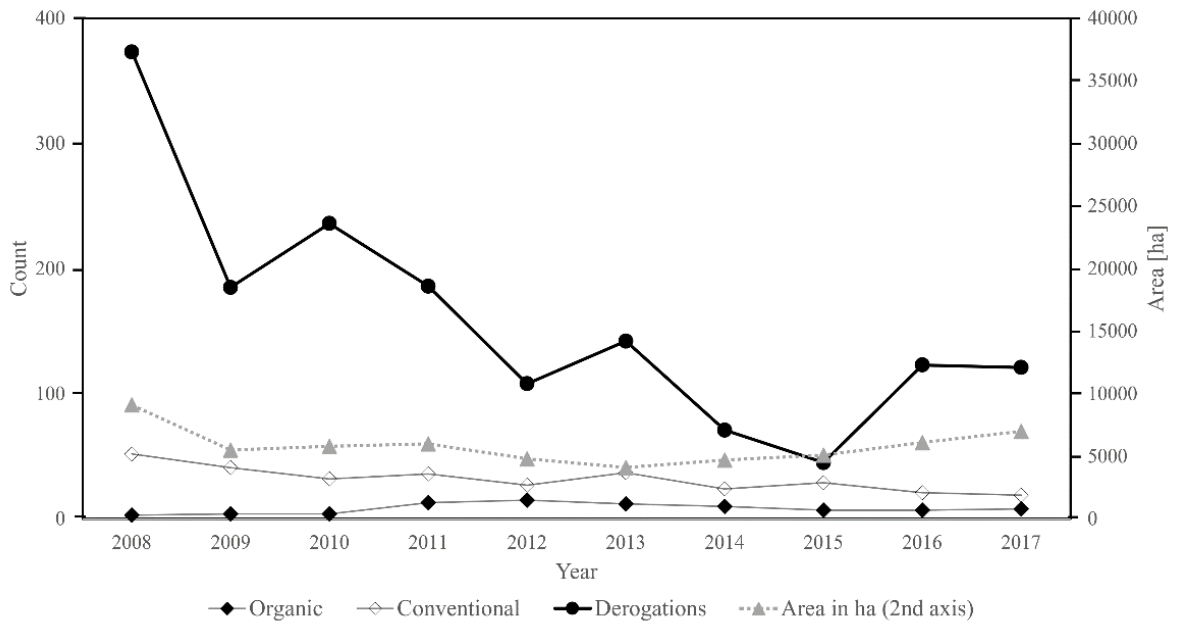


Figure A 17 An overview of field pea

Note: The left axis displays changes in supply of cultivars from organic multiplication (Organic), changes in cultivars requested from conventional multiplication (Conventional), and the number of derogations requested per year (Derogations). The right axis displays the corresponding organic crop area (Acreage) in hectares per year in Germany.

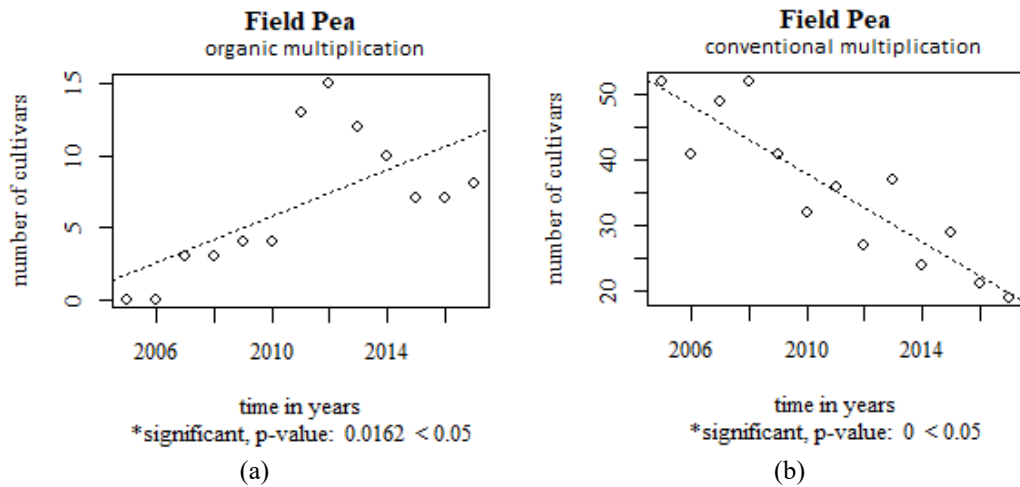


Figure A 18 Scatter plots with regression lines for field pea during 2005-2017 (a) the number of cultivars available from organic multiplication; (b) the number of cultivars requested from conventional multiplication

Table A 1 Summary of German organic farming acreage and number of derogations on the use of non-organic seeds of winter and spring wheat and rye

Year	Winter Wheat		Spring Wheat		Rye	
	Organic area (ha)	Number of derogations	Organic area (ha)	Number of derogations	Organic area (ha)	Number of derogations
2008	40500	201	6500	93	52000	267
2009	44000	180	6000	63	63000	224
2010	46000	120	8000	44	57000	92
2011	47000	190	9000	60	53000	244
2012	46000	213	10000	49	52000	180
2013	43500	141	8500	41	54000	173
2014	40500	199	8500	45	55000	93
2015	48000	97	10000	17	51000	94
2016	54000	327	9000	97	52000	271
2017	58000	126	11000	44	56000	122

Table A 2 Summary of German organic farming acreage and number of derogations on the use of non-organic seeds of winter and spring barley and spelt

Year	Winter Barley		Spring Barley		Spelt	
	Organic area (ha)	Number of derogations	Organic area (ha)	Number of derogations	Organic area (ha)	Number of derogations
2008	8500	177	13500	667	18000	111
2009	11000	50	12500	96	21000	40
2010	9500	44	13500	80	22000	33
2011	8500	79	14000	139	20500	77
2012	8500	67	14500	106	18000	77
2013	9000	61	14500	68	17500	47
2014	8500	45	12500	64	17000	115
2015	11000	70	16000	82	25000	157
2016	13000	53	17000	100	29000	56
2017	18000	108	19000	291	27000	37

Table A 3 Summary of German organic farming acreage and number of derogations on the use of non-organic seeds of oat, triticale and maize

Year	Oat		Triticale		Maize	
	Organic area (ha)	Number of derogations	Organic area (ha)	Number of derogations	Organic area (ha)	Number of derogations
2008	23500	571	21000	311	4500	152
2009	21000	101	24000	142	5000	284
2010	21500	80	25000	123	4400	430
2011	23000	177	24000	189	4000	334
2012	23500	320	22500	243	4500	274
2013	25500	90	24000	116	8700	138
2014	24500	58	25000	184	9300	16
2015	30000	54	27000	51	11000	25
2016	28000	129	26000	386	12000	22
2017	33000	399	31000	116	13000	21

Table A 4 Summary of German organic farming acreage and number of derogations on the use of non-organic seeds of field bean and pea and lupine

Year	Field Bean		Field Pea		Lupine	
	Organic area (ha)	Number of derogations	Organic area (ha)	Number of derogations	Organic area (ha)	Number of derogations
2008	5800	266	9100	373	8600	163
2009	6000	90	5500	185	7800	66
2010	8600	86	5800	236	9500	56
2011	8600	104	6000	186	9000	123
2012	7800	87	4800	108	7000	144
2013	7900	207	4100	142	6500	109
2014	9900	172	4700	71	6900	115
2015	12500	75	5100	45	8900	135
2016	12000	141	6100	123	9500	189
2017	15000	56	7000	121	11000	163

Table A 5 Summary of German organic farming acreage and number of derogations on the use of non-organic seeds of cabbage, carrot and onion

Year	Cabbage		Carrot		Onion	
	Organic area (ha)	Number of derogations	Organic area (ha)	Number of derogations	Organic area (ha)	Number of derogations
2008	230	626	1400	292	330	287
2009	200	226	1500	108	320	146
2010	200	254	1500	130	350	204
2011	200	217	1550	94	400	139
2012	516	209	1757	99	512	150
2013	525	203	1729	138	612	159
2014	607	214	1734	114	640	148
2015	584	256	1743	110	654	162
2016	541	201	2079	79	856	270
2017	695	442	2103	110	865	293

Table A 6 Summary of German organic farming acreage and number of derogations on the use of non-organic seeds of red beet and potato

Year	Red Beet		Potato	
	Organic area (ha)	Number of derogations	Organic area (ha)	Number of derogations
2008	240	111	8150	1239
2009	240	86	8350	612
2010	210	77	8200	778
2011	240	107	8300	1014
2012	364	83	8300	595
2013	295	106	8400	810
2014	481	175	8500	855
2015	470	205	8600	474
2016	609	243	8700	759
2017	698	260	8900	963

## Acknowledgments

This research would not have been possible without the support and collaboration of numerous individuals.

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Furthermore, I would like to highlight the support of Prof. Dr. Andreas Gattinger on my academic journey. His unwavering confidence in my abilities has been a critical factor in my progress. During moments of challenge, his support served as a powerful motivator, enabling me to complete this thesis. I am grateful for the academic freedom he provided, encouraging me to pursue innovative research approaches that have enriched my work and contributed to our field.

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I am proud to be part of the "FiBL Family." This network of trustworthy individuals, who share common values and goals in organic farming, inspires me every day to contribute to positive change.

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I'd like to thank my husband and our two wonderful kids. This work truly represents all of us, showcasing the strength and love of our family. My family is my strongest support system. They provide me with love and encouragement. I also have a strong group of friends who are important in my life. Together, we share good times and face challenges. We enjoy fun gatherings, travel together, and make the most of every moment.

Getting to know other people's perspectives has been a valuable experience to me. It's helped me understand their actions and motivations much better. Through my work, I've learned to recognize the cultural and emotional influences that shape how people behave. I honestly believe that understanding these factors is key to building better communication and making sound decisions. By embracing diverse viewpoints, I'm focused on improving dialogue, reducing misunderstandings, and collaborating on inclusive and effective solutions in our ever-complex social and professional lives.

## **Erklärung**

gemäß der Promotionsordnung des Fachbereichs 09 vom 07. Juli 2004 § 17 (2)

Ich erkläre: „Ich habe die vorgelegte Dissertation selbständig und ohne unerlaubte fremde Hilfe und nur mit den Hilfen angefertigt, die ich in der Dissertation angegeben habe.

Alle Textstellen, die wörtlich oder sinngemäß aus veröffentlichten Schriften entnommen sind, und alle Angaben, die auf mündlichen Auskünften beruhen, sind als solche kenntlich gemacht.

Bei den von mir durchgeführten und in der Dissertation erwähnten Untersuchungen habe ich die Grundsätze guter wissenschaftlicher Praxis, wie sie in der „Satzung der Justus-Liebig-Universität Gießen zur Sicherung guter wissenschaftlicher Praxis“ niedergelegt sind, eingehalten.“

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