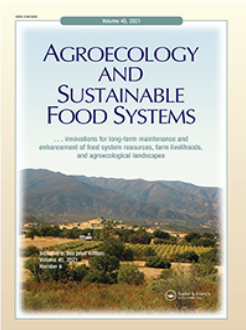

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Sow what you sell: strategies for integrating organic breeding and seed production into value chain partnerships

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ABSTRACT

The development of an independent organic breeding and seed sector poses a significant challenge for organic agriculture in Europe. It should deliver cultivars suitable to the principles and conditions of organic farming and secure the integrity of future product supply. This study seeks to identify promising pathways to address this challenge by analyzing value chain organization. It 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.

The results from the stakeholder dialogue show that a value chain partnership is a promising strategy to distribute the burden for refinancing breeding, as the whole organic sector would profit from organic breeding. A cross-sector pool funding strategy is proposed for joining forces among all value chain partners of the organic sector to invest in organic breeding and collectively secure the integrity of the future organic product supply. 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. The funding strategy is backed up by findings on market channels. Farmers who market their products through long value chains use less organic seed than those marketing through short value chains. This highlights the need to better integrate long organic value chains such as processors, traders, and retailers, and seed supply. Regardless of the marketing channel, farmers consider the development of organic breeding a vital measure to achieve higher organic seed use. This indicates that overcoming organic seed shortage is more likely to be achieved when also including breeding activities.

KEYWORDS
Organic plant breeding; organic seed; value chain partnership; farmer perceptions; marketing channel

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Background and objectives

The state of organic seed and breeding in Europe

In Europe, a constant reduction of public breeding programmes has taken place in the past decades (Aad Van et al. 2013). This development accompanied the privatization of the agricultural breeding and seed industry and, more recently, a substantial consolidation of the sector. Just three agrochemical firms controlled more than half of the global proprietary seed market in 2011 (Howard 2015) and this trend is ongoing. At the same time, the focus of crop improvement is increasingly targeting only a few major cash-crops for which breeding investments can be refunded through royalties on the production and sale of seed (Messmer et al. 2015). There is evidence from agroecological farming that a lack of breeding and consequently suitable cultivars is one of the main bottlenecks for crop diversification (Meynard et al. 2018; Vanloqueren and Baret 2008). These factors contribute to the decrease of agrobiodiversity in farmers' fields (Montenegro and Maywa 2016). These changes have generated public concern and may decelerate the transformation toward a more sustainable food system (Mooney 2017).

The organic farming movement emerged to find solutions for a more self-sufficient and locally adapted form of agriculture (IFOAM 2005). Many European countries are experiencing a rapid rise in the share of organic farms (Willer and Lernoud 2019). Yet, developing a strong and independent organic breeding and seed sector that addresses the needs of organic agriculture remains a key challenge. There are two bottlenecks to be overcome. Firstly, there is a shortage of seed multiplied under organic conditions (Solfanelli et al. 2019). As the phasing out of derogations for non-organic seed in EU organic agriculture by 2036 has been announced (New Organic regulation 848/2018), effective solutions need to be found which supply sufficient organic seed. Secondly, presently, for ca. 95% of all organic produce, cultivars were bred under conventional conditions (Lammerts Van Bueren et al. 2011). The new Organic Regulation recommends the use of cultivars suitable for organic agriculture. In this context, the European Commission has announced a 7-year temporary experiment to foster development and marketing of organic varieties within the scope of the EU seed marketing directives (New Organic regulation 848/2018 (39)). This experiment aims to show the suitability of organic cultivars for organic farming and to create easier market access for them. This opens a window of opportunity for the organic breeding and seed sector to become more independent of the conventional sector. Both bottlenecks could be overcome at once since there are several problems linked to both organic seed and organic breeding. With the phasing out of the derogations for non-organic seed, it is likely that many commonly used or newly developed conventional cultivars will no longer be available to organic farmers. This decrease in availability can be attributed to either the small size of the organic market or technical challenges to produce organic seed, such as high pest pressure or high costs of separate processing facilities. The commitment of the organic movement to only accept specific breeding techniques may further decrease cultivar choice, as emerging genetic engineering techniques, such as CRISPR-Cas9, could be widely adopted in future agricultural systems (BÖLW 2018).

Furthermore, organic agriculture differs from conventional agriculture with regard to agricultural crop diversity exploitation. Crop biodiversity organized in time (crop rotation) or space (crop association) is crucial in organic agriculture, which generates the need for breeding a wide range of crops with sometimes a relatively small total area. As organic agriculture aims for diverse crop species and locally adapted cultivars, it is expected that the area under production of a single organic-bred cultivar may remain relatively small, even if organic acreage share would grow rapidly in the future. Therefore, refinancing Organic Plant Breeding through a royalty system on seeds of protected cultivars will be insufficient for most crops (Kotschi and Wirz 2015). Moreover, most organic breeders do not want to protect their cultivars but motivate organic farmers to produce their own seed. This puts the prevailing system of refinancing breeding investments through royalties or seed sales to a test.

Approaches to overcome shortages of organic seed and suitable cultivars in the European organic food sector

As outlined above, alternative financing strategies to the prevailing refinancing system have to be identified for the organic sector. In reaction to this, a range of alternative crop improvement programmes have emerged, including initiatives with the aim to increase organic seed production and to facilitate organic cultivars release. In most cases, organic breeding initiatives rely on co-financing from various sources, which are often restricted to project-based or short-term engagement. For example, in Switzerland and Germany, the current common financing strategies for organic breeding initiatives are, in decreasing order of importance, pre-financing through foundations (52%), trade and processing (14%), donations from individuals (9%), public funding (8.5%), as well as other sources (Kotschi and Wirz 2015). These data reveal the fragmented nature of organic breeding funding.

However, with a current market volume of 37.3 billion euros in Europe in 2017, the organic food sector has become an essential part of the overall food industry. Organic products, both fresh and processed, can be found at farmers markets as well as in big retail outlets. The majority is marketed through supermarkets (Willer and Lernoud 2019). All organic value chain actors will be affected if there is a shortage of organic seed and cultivars. Thus, it is in the interest of a wide range of industry actors to acknowledge and address the individual challenges of the organic sector, such as the provision of organic seed and cultivars suited for organic agriculture. Furthermore, there is case study evidence that downstream value chain actors influence organic farmers' seed and cultivar choice. For example, two studies show that in France, organic vegetable growers tend to use more organic seed if they market their produce directly rather than through longer value chains (Le Doaré 2017; Rey et al. 2013). The same tendency was found in a study conducted in Canada (Levert 2014). This shows that a closer link to the end-consumer facilitates organic seed use. Furthermore, it is likely that given the current mainstream standards of longer value chains, e.g., with respect to uniformity and visual quality is still easier to meet market requirements when using cultivars from conventional breeding. The importance and influence of marketing channels on various farm management aspects, such as input and crop choices, has been established in numerous studies (Navarrete 2009; Schipmann and Qaim 2011; Xaba and Masuku 2013). As more traditional approaches, like refinancing breeding costs through royalties or seed sales, cannot be applied to many crops in organic agriculture, insights into the influence of marketing channels on seed and cultivar choice are important for encouraging and steering activities in value chain partnerships and designing public policies. These efforts will help achieve the targets for organic seed use and organic breeding promotion, set by the new Organic Regulation.

Approaches focusing on value chain partnerships

With declining public funding for breeding, institutional innovation seems to be an entry point for enhanced breeding activities. Both researchers and decision-makers acknowledge the importance of developing interventions that target collaborations along the agri-food value chain (Healy and Dawson 2019; Henriksen et al. 2010; Matopoulos et al. 2007). This involves for instance improved information flows about needs and challenges at different value chain stages and coordinated problem-solving mechanisms. It also often requires a reconfiguration of power distribution along the value chain. Rossi, Bui, and Marsden (2019) argue that equity can lead to substantially more sustainable agri-food systems. They outline a case of power shift from global to local value chain actors in wheat breeding. Another example is better linking seed producers and breeders to downstream value chain actors by establishing collaborative structures, that focus on addressing the needs of both sides (Altaye and Mohammed 2013). Chable et al. (2020) demonstrated the usefulness of participatory breeding approaches linked with local short supply chains to enrich biodiversity from farm to fork. There are some small-scale examples where partnership-based value chain solutions in the organic seed and breeding value chain have succeeded in establishing sufficient organic seed and cultivar supply in Europe (Naturata International 2015; Verrière, Nuijten, and Messmer 2019). Other larger scale examples can be found in the textile industry, i.e. the Organic Cotton Accelerator, that supports organic cotton breeding through a pool funding by value chain actors (Messmer, Joshi, and Riar 2019). Additionally, a pool-funding strategy is considered to tackle other challenges of the agricultural sector in Europe, such as animal welfare issues (Initiative Tierwohl 2020).

Objectives and research questions of this study

In this study, we focus on developments in the EU organic seed and breeding sector. We outline novel models for financing the growth of organic breeding through the development of value chain partnerships. In addition, we advance the understanding of the role of downstream value chain actors, regarding their influence on organic seed use and farmers' perception of breeding needs for the organic sector. Our research is the first to conduct a multi-step stakeholder dialogue to develop a model that could boost the organic seed and breeding sector, based on value chain collaboration, underpinned by an analysis of marketing channel effects using a large sample of organic farmers across Europe. Marketing channels are used as a proxy for the effect of downstream value chain actors on farmers' organic seed use. Through the combination of this data, we aim at giving a comprehensive overview of the perspectives of the most relevant actors of the seed and breeding value chain stages in European organic agriculture, i.e., breeders, seed producers, farmers, and downstream actors.

In particular, our study was based on the following research questions:

(i) Which financing strategies for breeding for the organic sector exist, what are their bottlenecks and potentials for upscaling?

(ii) Against this background, what would a promising intervention targeting value chain collaboration look like to boost organic breeding and seed production?

(iii) What effect do organic marketing channels currently have in terms of organic breeding and seed use at the farm level? How do they influence farmers' perception of the importance of organic seed and breeding?

Materials and methods

An integrated research approach was applied in this study by combining and analyzing different data types, including (i) qualitative data from two multi-actor workshops, (ii) qualitative semi-structured interviews with key breeding and seed experts in Europe and with market players of the food processing and retailer sector and (iii) quantitative data from a multi-country online farmer survey in Europe. The integrated research approach allowed us to exploit the most suitable data sources for answering the above-stated research questions.

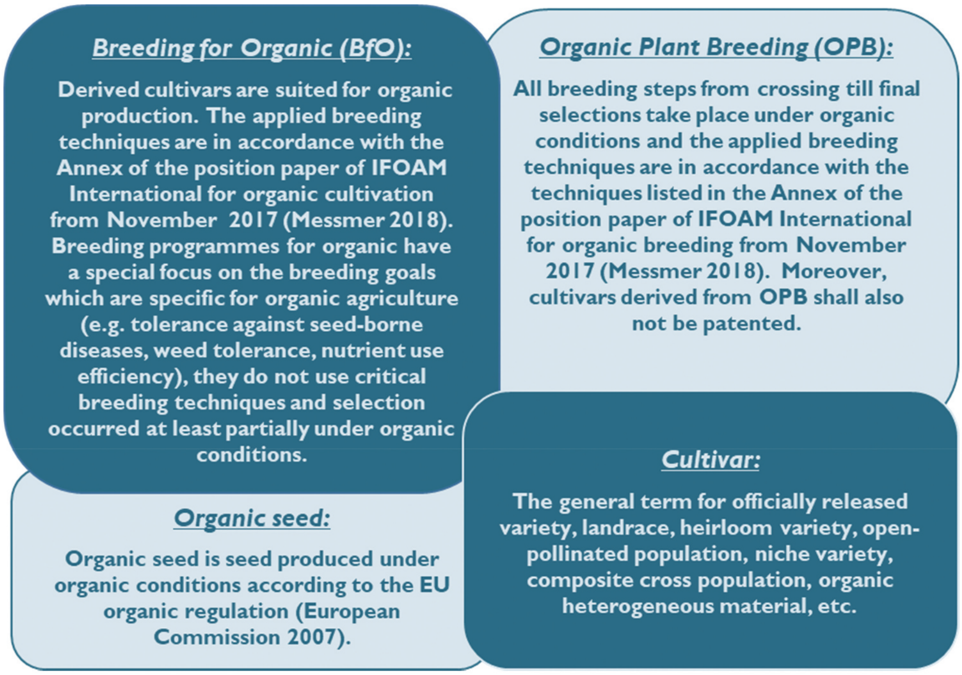


Figure 1. Definitions for organic cultivar development and organic seed.

The study relies on the definitions of organic breeding, breeding for organic, cultivar and organic seed as outlined in the Horizon2020 project LIVESEED (Figure 1) (LIVESEED 2020).

Assessment of multi-step stakeholder dialogue on strategies for integrating organic breeding in value chain partnerships

Data collection

A multi-step stakeholder dialogue (Dodds and Benson 2012) was carried out between 2018 and 2019 comprising (1) explorative interviews with breeders and seed producers in Europe and (2) two formal participatory workshops with all relevant stakeholders and (3) bilateral meetings of scientists with selected stakeholders, including organic breeders, farm advisors, seed producers, researchers, processors, retailers, organic farming associations and donation agencies targeting the refinement of the workshops' outcomes. The objective of the stakeholder dialogue was to identify existing financing strategies for organic breeding and to develop a long-term, large-scale financing concept for organic breeding that represents the views of all relevant stakeholders.

At first, twenty-five explorative key informant interviews representing public breeding institutions, breeding initiatives, and breeding and seed companies of the conventional and organic breeding and seed sectors in 12 European countries were conducted. This allowed a better understanding of how organic breeding is financed at present. On this basis, we identified promising financing strategies for organic breeding, as gray and scientific literature is scarce. Among the 25 interview partners, 19 interviewees represented entities directly involved in organic seed production and/or breeding or breeding for organic. The financing strategies of these actors were identified and analyzed (see next sub-section for further information about the analysis) as to their potential for upscaling and their shortcomings. Key informants and relevant actors for the interviews were identified with additional support of the LIVESEED project partners and its stakeholder platform.

The interview results were used as the basis for discussion in two workshops (September 2018 and February 2019) and bilateral meetings between scientists and selected stakeholders aiming to co-develop criteria for a cross-sector pool funding strategy and establish framework conditions that can be applicable at the European level. During the workshops and bilateral meetings, key issues regarding organic breeding integration into value chain partnerships were discussed. The included actors were organic breeders, farm advisors, seed producers, researchers, processors, retailers, organic farming associations and donation agencies that already fund organic breeding.

The first workshop targeted organic value chain stakeholders from Germany. In this country, several organic breeding initiatives and small-scale experiences of value chain collaborations for financing breeding are already in place. Comments from seed and breeding experts (21), processors (4), retailers (7), associations (10), foundations (3), and communication experts (2) were collected. The second workshop was used to expand the discussion with breeders, researchers, retailers and organic producers active at the European level. Twenty-three participants from eight countries from Central and Eastern Europe attended the workshop. The participants were breeders (7), researchers (7), NGOs (2), seed producers (3), retailers (2), organic farmers (1), and organic associations (1).

To summarize the process, based on existing financing strategies and experiences as well as ideas for the improvement of breeders that had already built a relationship with value chain partners, a core group of natural and social scientists developed essential criteria for a cross-sector financing strategy. During the outlined workshops and bilateral meetings, the identified criteria for long-term collaboration along the value chain were validated and additional criteria identified and integrated as a multi-actor effort.

Data analysis

The material from the interviews, meetings and workshops was qualitatively analyzed using content analysis. Content analysis aims to obtain a broad and condensed description of phenomena. As an outcome, concepts or categories are derived (Elo and Helvi 2008). Specifically, organizational models and financing strategies for organic breeding were described and analyzed as to their advantages, shortcomings and resulting potential for scaling up or out. With this knowledge as a basis, further interviews, and workshops concerning a financing strategy and organization model for organic breeding at a European level were conducted. As a part of this process, we developed a strategy proposal for including organic breeding in value chain partnerships. This strategy proposal operationalizes the knowledge collected and generated during the stakeholder dialogue, and builds on experiences of previous examples of similar approaches. Potentials and challenges of such a strategy for boosting the organic breeding sector were identified.

Analysis of farmers' behavior and downstream value chain interactions

Data collection

To complement the findings from the key-informant interviews and stakeholder dialogue, data from an online survey targeting organic farmers was analyzed. The survey was conducted between November 2018 and June 2019 and distributed through the networks of partners involved in the Horizon2020 project LIVESEED, including 23 breeding & research institutes, seven breeding companies, eight seed companies, and 11 organic associations.

752 complete entries by farmers from 20 countries from Central, Northern, Southern, and Eastern Europe could be used from the 1,475 total accesses to the survey. Since neither the information needed for probability nor for cluster sampling of the organic farm population was readily available due to privacy restrictions, non-probability opportunity sampling was applied. This is a widely used sampling strategy in rural sociology to tackle the challenge of data collection at the farm-level (Abdu-Raheem 2014; Ferguson and Kepe 2011; Sangkapitux et al. 2017). In our case, all farmers fulfilling the requirement for participation (i.e., that they grow at least one of 19 specified important crops organically) could complete the survey. The investigated crops are, apples (*Malus domestica*), grapes (*Vitis vinifera*), pea (*Pisum sativum*), grain maize (*Zea mays*), barley (*Hordeum vulgare*), oats (*Avena sativa*), lupine (*Lupinus angustifolius*), potatoes (*Solanum tuberosum*), cauliflower (*Brassica oleracea* var. botrytis), carrots (*Daucus carota*), onion (*Allium cepa*), tomatoes (*Solanum lycopersicum*), soft wheat (*Triticum aestivum*), soybeans (*Glicine max*), alfalfa (*Medicago sativa*), durum wheat (*Triticum durum*), strawberries (*Fragaria* x *ananassa*), olives (*Olea europea*), and a forage mixture.

Respondents could indicate multiple marketing channels they use in the survey, i.e. marketing via supermarkets, processors or traders, specialized organic retailers, cooperatives and direct marketing. To obtain groups that are large enough for meaningful econometric analysis, we re-coded the variable to match our outcome of interest, i.e. the comparison of responses grouped as short *vs* long value chains. This resulted in two groups: (1)

Farmers predominantly marketing through supermarkets, traders, and cooperatives (a proxy for long value chains); (2) Farmers marketing directly to consumers (a proxy for short value chains).

Out of the 25 questions in the survey, five outcome variables were of interest for this study:

(i) *Attitude toward organic breeding*: This is a 5-point Likert-scale statement 'more breeding for organic farming would increase organic seed use with 1 indicating strong disagreement and 5 strong agreement. It is an indicator of the farmer's attitude toward the potential of increasing organic seed use through more targeted breeding in the organic sector. Thus, this outcome variable shows if, according to the farmer's perception, increasing the availability of organic cultivars would encourage the use of organic seed.

(ii) Organic seed use per farm: This outcome variable is calculated as a percentage of organic seed use of the overall seed use at the farm level. It is an indicator of the organic farmers' actual behavior in terms of their use of organic seed.

(iii) Buyer expectation: The variable is specified as a 5-point Likert-scale statement 'my buyer expects me to use organic seed', with 1 indicating strong disagreement and 5 strong agreement. It captures the farmers' perception of their buyers' expectations about organic seed.

(iv) Farmers' attitude toward organic seed: This variable is a 5-point Likert-scale statement 'the use of organic seed is important for the integrity of organic farming', with 1 indicating strong disagreement and 5 strong agreement This outcome variable displays the attitude of the organic farmers toward organic seed.

(v) Farmers' perception of the organic seed price: This variable is a 5-point Likert-scale statement 'the organic seed price is prohibitive' with 1 indicating strong disagreement and 5 strong agreement. This outcome variable indicates if farmers find the organic seed prices too high.

Data analysis

The comparative analysis of marketing channels required data pre-processing to overcome the unbalanced composition of the two groups (responses grouped as short *vs* long value chains) arising from the opportunity sampling strategy used. The sampling strategy may have caused a bias toward a higher response rate from farmers who are motivated to use organic seed, even if it is not compulsory. We applied various weighting methods to address the bias that will be explained in the following. Through the application of these weighting methods, the dataset can still yield relevant results, e.g. explaining differences in quantity of used organic seed between different farmer groups.

To control for confounding factors (e.g., gender, age, farm size, crop specialization of farm depicted by the percentage of area on which vegetable grown (on remaining area, arable crops are grown), education of farm manager, received trainings, and location), we employed a doubly robust data pre-processing approach in our comparative analysis. This technique combined inverse probability weighting and regression adjustment, using the treatment effects routine in STATA 15 (Cerulli 2017; Drukker 2016). These confounders were selected to ensure the inclusion and balance of the most relevant independent farm and farmer characteristics. At the same time, model convergence was still warranted. To maximize the predictive power of the chosen model, quadratic terms of the continuous variables were included and sufficient balancing was tested and confirmed with the overidentification test. Standard errors are specified to allow for intragroup correlation with the country indicator as the cluster variable. A similar approach was applied, for example, to compare different levels of farmers' value chain integration and their effect on farm household food security in Tanzania (Kissoly, Faße, and Grote 2017) and to determine the impact of marketing through agricultural cooperatives on farm household income in the Sichuan province, China (Liu et al. 2019). We adjusted our sample of observational data through the use of probability weights. These were calculated based on the known number of organic farmers per country. Adjusting the sample by country is the best suited approach, as the regulations regarding organic seed are implemented at national level, and thus differ significantly between countries. As the number of observations in each country was not directly indicative of the total number of organic farms per country or in the entire population, the number of observations in each country was weighted in the model using the probability weights routine in STATA 15. Here, the inverse probability of the selection of a farmer in a given country helped to reflect more adequately the importance of individual sampling units.

In Table A2 in the Appendix, a substantial improvement of covariate balance for the selected control variables by the ipwra balancing strategy can be observed. In most cases, the standardized differences of the weighted covariates moved closer to zero, and the variance ratios moved closer to one. A perfectly balanced covariate would have a standardized difference of zero and a variance ratio of one. The overidentification test for covariate balance shows that the pre-processing method ipwra sufficiently balanced the samples (chi-squared value of 14.4 with 12DF, p-value of 0.27). The compared subsamples were re-weighted from 317 to 378.4 in the case of the subsample of farmers using longer chains, and from 435 to 373.6 in the case of the subsample using short chains.

To verify the robustness of results, we additionally applied the method of propensity score matching for comparison. However, probability weights and standard errors allowing for intragroup correlation with the country indicator as the cluster variable are not implemented in the treatment effects routine in

STATA 15; thus, the results are not as accurate as inverse probability weighting combined with regression adjustment (ipwra). Moreover, if the propensity score model is miss-specified, there is no control mechanism as in ipwra (Liu et al. 2019).

Results

Multi-step stakeholder dialogue on strategies for integrating organic breeding in value chain partnerships

A number of different actors, including commercial companies, nonprofit organizations, and public institutions, conducts breeding activities. The breeding programmes in the organic farming domain can be grouped in Breeding for Organic (BfO, Figure 1) and Organic Plant Breeding (OPB, Figure 1). Most Organic Plant Breeding activities are currently taking place in Central Europe (36), with 12 activities present in Southern Europe, 7 in Northern Europe, and only 3 found in Eastern Europe. An actor mapping confirmed these numbers (Nuijten, Vonzun, and Messmer 2019). Breeding for Organic (BfO) activities usually integrate breeding goals of the organic sector into their running breeding programme. For example, in Austria, Latvia, and Hungary, there are BfO initiatives in which crosses and early generation selections are performed under conventional conditions, and selection at later generations and cultivar testing are conducted under organic conditions.

Based on interviews with 23 key informants of both conventional and organic seed and breeding sector, the following financing strategies and linked organizational models for breeding for the organic sector could be identified and their potential for scaling up or out assessed. An overview of advantages and shortcomings of the combinations of financing strategies and organizational models is presented in Table 1.

Refinancing through seed sales or royalties, with mostly shared organic and conventional programmes, was mentioned as the most used financing strategy for medium-sized conventional seed companies (Breeding for Organic, Figure 1). By combining their activities for the conventional and organic sector they can harness synergies in the breeding process, be more cost-efficient and cross-finance the investment into organic breeding goals via conventional seed sale. Upscaling would be readily possible if the organic market continues growing and the usage of organic seed is enforced by the new organic regulation. The main bottleneck, which would affect Breeding for Organic, are restrictions in breeding techniques by the organic sector. However, Breeding for Organic is a compromise that cannot always adequately address all breeding goals relevant for the organic sector, as not all selection steps are conducted under organic conditions. The introduction of semi-dwarf genes for yield increase in high-input wheat cultivation is a salient

Table 1. Existing financing strategies and organizational models for breeding for the organic sector, advantages and shortcomings for scaling up or out (based on interviews with stakeholders).

Financing strategy Organizational model	Refinancing through seed sales or royalties	Pre-financing through public funding	Pre-financing through donations	Pre-financing through food trade actors
Medium-sized conventional seed company with combined breeding programmes for organic and conventional farming (Breeding for Organic)	**Advantage**: -Resource-efficient breeding process -Upscaling possible if organic market increases **Shortcoming**: -Organic breeding goals cannot be fully addressed, because the breeding process is mainly conducted under non-organic conditions -Possible restriction in breeding techniques due to organic regulation (Interviewed actors: 7)	-	-	-
Small organic breeding company or initiative (Organic Plant Breeding)	**Advantage**: -Can cover part of an investment **Shortcoming**: -Insufficient return on investment due to small production areas and farm-saved seed (Interviewed actors: 3)	**Advantage**: -Transparent distribution -Supports collaboration with researchers and other breeders **Shortcoming**: -Only short-term research-focussed funding -Practical breeding work is not publicly funded -High administrative burden (Interviewed actors: 2)	**Advantage**: -Low administrative costs **Shortcoming**: -Unstable source of income for breeder -Only a few foundations provide substantial support to Organic Plant Breeding -Difficult to transfer to other countries (Interviewed actors: 3)	**Advantage**: -Stable source of income for breeder -Transparent distribution -Close collaboration between breeders, processors and traders to contribute to determining breeding goals **Shortcoming**: -High voluntary commitment of food value chain actors needed (Interviewed actors: 4)

(*Continued*)

Table 1. (Continued).

Financing strategy Organizational model	Refinancing through seed sales or royalties	Pre-financing through public funding	Pre-financing through donations	Pre-financing through food trade actors
Farmer-breeders organization (Organic Plant Breeding)	**Advantage**: -Added value and partial return of investment through direct marketing or short value chains **Shortcoming**: -High financial risk of farmer -Upscaling to reach longer value chain and larger geographical coverage (e.g. to European level) is difficult (Interviewed actors: 4)	-	**Advantage**: -Low administrative costs **Shortcoming**: -Unstable source of income for farmer breeders (Interviewed actors: 2)	-
Public breeding institute (Organic Plant Breeding, Breeding for Organic)	-	**Advantage**: -Secure long-term funding based on the needs of society **Shortcoming**: -Public funding has been declining -Practical breeding work is only funded in a few countries, mainly focused on conventional farming (Interviewed actors: 4)	-	-

example for competing breeding goals between organic and conventional agriculture. This resulted in cultivars with short straw and consequently, a reduced weed suppression ability and reduced nutrient uptake efficiency (Lammerts Van Bueren et al. 2011). Most of the key informants interviewed agree that Organic Plant Breeding activities cannot be entirely refinanced through seed sales, considering the characteristics of organic farming. These include diverse crop rotations and therefore a high breeding demand for small crop areas. Moreover, many Organic Plant Breeding initiatives are nonprofit organizations that refrain from variety protection and breed with open-pollinated cultivars that can be multiplied by farmers (Wirz, Kunz, and Hurter 2017).

Decentralized farmer-breeders organizations were mentioned as a relevant organizational model using a refinancing strategy via direct sale or short value chains, as well as donations. Small-scale local farmer-based breeding initiatives are ongoing in France (Réseau semences Paysannes), Italy (Rete Semi Rurali), Spain (Red de semillas) and Portugal (Associação Zea Mais). However, scaling up or out such initiatives to supply also long value chains and to a European level would require establishing extensive decentralized structures with a very high degree of voluntary farmer involvement in breeding activities.

Public funding and donations play a significant role in financing companies conducting Organic Plant Breeding. **Public funding** is in general based on research-driven projects (e.g. H2020 DIVERSIFOOD, LIVESEED, ECOBREED and BRESOV), which contribute to breeding research but do not cover the cost for the close-to-market practical breeding work. Although public breeding programmes in Europe have been reduced and replaced by commercial enterprises, they still play a major role in several countries (e.g., Hungary, Romania, Latvia, Italy, Switzerland). However, their engagement in organic breeding is still in its infancy but could be upscaled if political decisions toward independent and sustainable agriculture and food production in Europe were made.

Private foundations with specific funds dedicated to organic breeders, such as *Zukunftsstiftung Landwirtschaft* in Germany, currently play a major role facilitating the activities of the forerunner organic breeding initiatives in Central Europe. However, in many cases, upscaling or scaling out to other countries is difficult as foundations are often committed to specific geographic regions and prefer start-up financing. Available finances also depend on the interest rates of the foundation capital and other arising social challenges. These limitations constrain the sustainable growth of the organic breeding sector across Europe.

Many interviewees listed the involvement of **value chain actors** as a promising financing strategy for scaling up or out as the whole sector is profiting from organic breeding. This distributes the burden of refinancing breeding, now solely carried by breeders and farmers, amongst the value chain partners. There are several examples on a rather small scale where a close collaboration of value chain actors has led to the use of an organically bred cultivar or a cultivar particularly suited to organic conditions and fair compensation of breeders and farmers. These initiatives are described in the following paragraphs. Further, the success factors of these initiatives are explained, as emerged from the interviews.

The *Fair-Breeding®* initiative is an example of a small-scale pool-funding model based on value chain collaboration in Germany, where food trade actors can contribute a percentage of their revenue of organic product sales to fund organic breeding. Value chain actors identify a breeding need and guarantee funding for a 10-year duration. With this fund, three new open-pollinated cauliflower cultivars could be bred since 2008 by Kultursaat e.V. The main marketing channel are organic shops (Wirz, Kunz, and Hurter 2017).

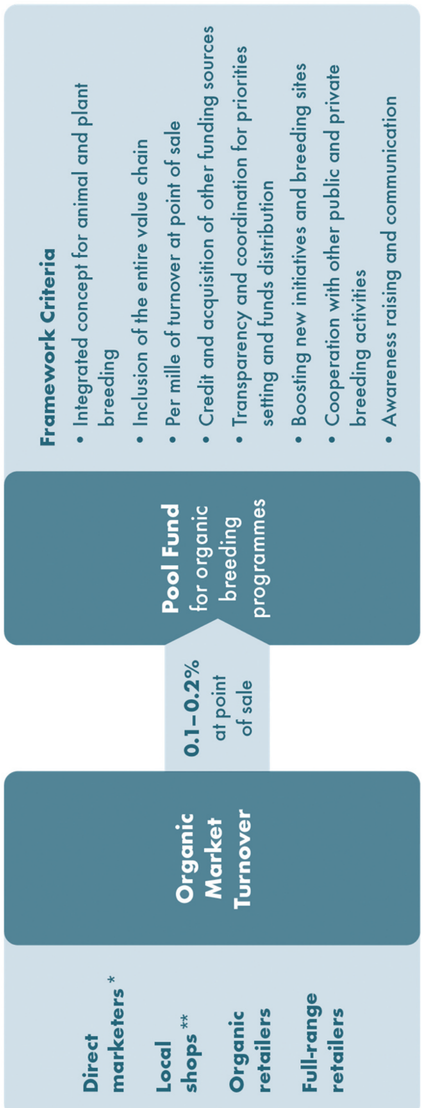
In 2013, the *Organic Seeds Sunflower* initiative was founded by 10 organic companies to support the breeding organizations GZPK and Sativa in developing organic high-oleic sunflower cultivars in Switzerland. Financing was secured through the organic companies joining the partnership (AOT 2020). All supply chain members are involved; farmers, oil producers and distributors, contributed together with the organic breeders at developing sunflower cultivars suitable for organic agriculture. The success factors that could be deducted from these examples are longer-term funding, a clear breeding goal, excellent communication among breeders, and downstream value chain actors, and a marketing strategy (Verrière, Nuijten, and Messmer 2019).

Additional case study evidence from the Netherlands, France, and Switzerland on the introduction of individual disease-resistant apple and potato cultivars into the organic market through value chain partnerships, show the importance of a good communication structure, shared values of value chain actors, and a clear marketing strategy (Nuijten et al. 2018).

However, these funding options are fragmented and by far do not cover the investment needed for organic plant breeding for a broader range of crop species in different European countries (Kotschi and Wirz 2015). Moreover, the annual acquisition and reporting binds resources of breeders and prevents new actors from committing themselves to organic breeding. Therefore, a broader and more sustainable funding is needed for organic breeding, which is vital for the future integrity and development of the organic sector.

The multi-stage stakeholder dialogue comprised of several bilateral meetings and two workshops allowed to consult different organic value chain actors and enriched the information collected with the qualitative interviews. This activity aimed at systematizing the opportunities for integrating organic breeding in value-chain partnerships and developing a strategy for pool funding of organic breeding in Europe (Figure 2).

The central concept of the pool funding is that all value chain partners of the organic sector join forces to invest in organic breeding to secure the integrity



* Farm gate sales, farmers markets, box schemes, farmers markets
** Bakeries, butcheries, specialised vegetable and fruit shops, health shops

Figure 2. Cross-sector pool funding strategy.

of their future supply. For example, one or two per mille of turnover at the point of sale of all organic products and market chains would feed a pool fund, which is coordinated and distributed to individual organic breeding initiatives (Figure 2). In the following, the framework criteria that emerged from the multi-stakeholder dialogue listed in Figure 2 are further explained.

Integrated concept for animal and plant breeding: The outcomes of the multi-step stakeholder dialogue showed that high demand for organic breeding exists equally in animal and plant production at the European level. Therefore, an overarching pool funding strategy is proposed to facilitate the development of an integrated concept for animal and plant breeding which avoids competition and promotes cooperation between both organic breeding sectors.

Inclusion of the entire value chain: The whole value chain should be involved in the cross-sector pool funding to ensure that the needs of the sector for adequate cultivars and animal breeds are covered and that all actors take responsibility to achieve sufficient funding. Mutual benefits of the pool funding concept for all value chain actors were identified and will have to be clearly communicated when upscaling efforts. Organic breeding can support processors and traders to provide continuous innovation to the market (e.g., with cultivars for a particular use such as grain legumes for meat-free protein meals). The investment on the integrity of the products including breeding and cultivar choice can be used as a commercial narrative to differentiate the organic sector for a long-term investment perspective and for the commitment toward ensuring future food security, food quality and climate robust agriculture. Increase in food diversity, nutritional value and taste of the products are additional aspects that can motivate retailers.

Per mille of turnover at point of sale: Licenses at the product level tend to lead to distortions of competition or disproportionate price increases; therefore, a flat rate at the point of sale is foreseen as a better funding option. Here, extracting a percentage of the organic turnover (similar to a VAT) at the point of sale as engagement from market partners of the organic sector is proposed. An amount in the order of 0.1–0.2% of organic turnover is seen as affordable by food trade actors and has a substantial impact on the financing of organic breeding activities when looking at the European organic turnover. For example, the sales volume of organic products in Germany was 10.9 Billion € in 2018 (Willer, Helga, Bernhard Schlatter, Jan Tràvnìcek, Laura Kemper, and Julia Lernoud. 2020. The World of Organic Agriculture 2020), and 0.2% would amount to 21.8 Million €. With an approximate annual breeding budget need for a new cultivar of 200,000 €, over 100 new cultivars could be produced, if food trade actors in Germany committed to participating in the pool funding concept for around 10 years. An acute breeding need for around 50 plant cultivars and 50 animal breeds was identified during the stakeholder process.

This type of standardized funding would allow a collective pre-commercial investment and long-term commitment of the food industry to facilitate the organic breeding sector in ensuring a constant supply of cultivars and animal breeds.

Credit and acquisition of other funding sources: Existing commitments of organic associations, processors and trading companies in organic breeding through donations or other well-functioning structures should not be curtailed. Moreover, funding contributions already made could be credited (e.g. via blockchain) and included in the transparency management of the pool funding strategy. In addition, more public funding could be attracted, and public-private cooperation could be developed if there is evidence of financial participation by the sector.

Transparency and coordination for priorities setting and funds distribution: Transparency of fund allocation and of the definition of breeding goals was identified as a key factor to a successful upscaling of value chain partnerships in organic breeding. Therefore, an independent coordination office for these purposes should be set up. Value chain actors (traders, processors, farmers, advisors, organic associations) should be involved in the strategic management, and an advisory committee of breeders and experts should be consulted for matching the requirements of all stakeholders in breeding priorities setting and programme selection. Criteria and methods for transparent allocation of funds need to be developed together with independent monitoring protocols of the breeding programmes financed to ensure that impact objectives are achieved.

Boosting new initiatives and breeding sites: In addition to existing initiatives, new initiatives and breeding sites should also be financed, and active promotion of young breeders must be pursued.

Cooperation with other public and private breeding activities: Close collaboration with other public and private breeding organizations to improve performance is advisable. Increased cooperation between organic breeders and breeders who consider organic breeding goals ("BfO"), both in the animal and plant sector, could create positive synergies. By forging and maintaining alliances, e.g. with animal protection organizations, breeding associations and other breeders' initiatives using organic breeding, existing networks can be strengthened, expanded professionally and the efficiency of organic breeding can be boosted.

Awareness-raising and communication: The importance of breeding for ensuring the independence of the organic sector and the integrity of organic products emerged as a crucial framework issue to be addressed. The communication of the commitment toward organic breeding and the reasons for this choice should be shared with consumers. It was suggested by stakeholders that the use of simple slogans, such as "We promote organic breeding", could strengthen the competitiveness and meet customers'

Table 2. Farm-level covariates of respondents of farmer survey for the two groups of short and long value chains.

Conditioning variables	Short value chain	Long value chain
n	**435**	**317**
	mean (standard deviation)	**mean (standard deviation)**
Gender of respondent (female = 1)	0.34 (0.22)	0.22*** (0.17)
Age of respondent (years)	47.9 (11.2)	47.4 (12.9)
Farm size (ln[ha])	2.62 (1.85)	3.96*** (1.44)
Time since conversion to organic farming (ln[years])	2.21 (1.05)	2.22 (0.95)
Received training in the last 10 years (yes = 1)	0.77 (0.18)	0.74 (0.20)
Crop specialization (% of vegetable area, on remaining area, arable crops are grown))	0.54 (0.44)	0.32*** (0.4)
Education of respondent	**n %**	**n %**
None	91 20.9	64 20.2
Apprenticeship	133 30.6	118 37.2
College/university degree	211 48.5	135 42.6

expectations for fully independent organic production without distorting the market.

As a summary, we propose a cross-sector pool funding strategy to support the development of an independent organic breeding sector that addresses the breeding needs of organic agriculture. Identified major success factors are long-term commitment of food trade actors to invest in a pool fund, awareness-raising on the importance of breeding, centralized coordination and administration of the pool fund, and a high level of transparency in the process. In the following, these results are complemented with some insights into organic farmers' behavior and attitudes regarding organic seed and

Table 3. Average treatment effects (**ATE**) of marketing channels on organic seed use, buyer relations and farmers' attitudes toward organic seed using ipwra.

Outcome variables	PO mean of short value chain (VC)	PO mean of long VC	ATE of long VC as compared to short VC	Significance level	ATE as % of PO mean
Organic seed use per farm (Proportion)	0.75 (0.02)	0.65 (0.03)	−0.10	***	−13.3
Farmers' attitude toward the need of organic breeding to improve organic seed use (Agreement 1–5)	3.71 (0.09)	3.72 (0.06)	0.01	n.s.	0
Farmers' perception of buyer expectation to use organic seed (Agreement 1–5)	3.90 (0.13)	3.77 (0.19)	−0.13	n.s.	−3.4
Farmers' attitude toward organic seed to improve integrity of organic farming (Agreement 1–5)	4.42 (0.06)	3.93 (0.12)	−0.49	***	−11.1
Farmers' perception of too high organic seed price (Agreement 1–5)	3.17 (0.15)	3.33 (0.11)	0.16	*	5.1

Note: Significance levels * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$, Standard errors in brackets; Agreement scale: 1 = strongly disagree to 5 = strongly agree; PO = Potential outcome breeding according to their main marketing channels. We chose to include these results as farmers have a central role in the development of agricultural value chains, and especially in seed and cultivar choice.

Insights into farmers' behavior and downstream value chain interactions

Farmers are at the center of agricultural value chains and thus, taking into account their perspective is of undeniable importance when analyzing the role of value chain actors on seed and cultivar choice. The two groups of farmers (short *vs* long value chain) in the sample differ significantly in terms of gender, farm size, crop specialization (Table 2), and geographic area (Appendix Table A1). Minor differences were observed for age, training, and education level. Descriptive statistics on the number of crops per farm and location can be found in Table A1.

After the correction of sample imbalance through ipwra, we estimated the average treatment effects (ATE) of marketing channels on farmers' actual use of organic seed and this attitude and perception related to organic seed (Table 3). The most striking difference is that farmers who market to a supermarket, trader, or to a cooperative use 10% less organic seed than farmers marketing directly to consumers (short value chain). On average both groups consider the need for organic breeding as an essential measure to increase the use of organic seed across several important crops (rated as medium to high), with no significant differences between the two groups (Table 3). The farmers' perception of the buyers' expectation regarding their use of organic seed was comparably high for short (3.9) and long value chains (3.8). In contrast, farmers' attitude toward the importance of organic seed for the integrity of organic farming differed significantly between the two groups (Table 3). Farmers' marketing to short value chains strongly agree that the use of organic seed is vital for the integrity of organic farming (4.4 ± 0.06), whereas farmers marketing to longer chains agree significantly less with this statement (3.9 ± 0.12). High priced organic seed is seen as an obstacle by both groups; however, the farmers marketing through long value chains agree significantly more with this statement (Table 3). Results have been confirmed using Propensity score matching. We can thus ensure certain robustness of our results.

Differences of means tested using a two-sample t-test with equal variances
Significance levels * $p < .05$, ** $p < .01$, *** $p < .001$

Discussion and conclusion

Overall, interviews with key informants and a stakeholder dialogue involving organic breeders and food trade actors revealed that collaboration between food trade actors and organic breeders in the form of a cross-sector pool funding concept could potentially tackle organic seed and cultivar shortage. Based on literature and our interviews some smaller-scale value chain partnership-based solutions already exist and have proved to be successful (Naturata International 2015; Verrière, Nuijten, and Messmer 2019). Furthermore, there is much evidence that close collaboration of agricultural supply chains has a positive impact on their functioning (Altaye and Mohammed 2013; Naspetti et al. 2011). The coordinated strategy that we propose as multi-actor group as result of the stakeholder dialogue would support to overcome the current limitation of segmented donations. A pool funding concept coordinated by the Organic Cotton Accelerator, has already been realized in 2017 for participatory organic cotton breeding ("Seeding the Green Future") supported by the textile industry (e.g., C&A, H&M, Inditex, Tchibo, Eileene Fisher, Kering) (Messmer, Joshi, and Riar 2019).

Moreover, a strategy similar to the pool funding that we propose for the breeding sector is also discussed for addressing other challenges of the agricultural sector in Europe. For example, in Germany a similar concept is proposed for addressing animal welfare issues at the national level (Initiative Tierwohl 2020). However, the current cases of value chain partnership-based breeding strategies are concentrated in Central Europe and focus on single breeding programmes. Tackling these challenges requires increased investments into organic breeding on the European level, shared responsibility along the value chain and a strategy for cross-sector collaboration that allows for pool funding collection and redistribution according to the needs and requirements of the involved actors.

From our interviews emerged, (i) different regional development level of the organic breeding sector (scattered presence of organic breeding programmes), (ii) different organizational and financing models (public sector, public-private cooperation, decentralized participatory programmes), and (iii) different regional importance for current funding sources (research funds, private donations, community contribution in-kind). These differences need to be taken into account to exploit and adapt the cross-sector pool funding strategy in different contexts. Framework criteria of the pool funding strategy might need to be refined for practical implementation, and local adaptation of the strategy for integration based on regional organic sector peculiarities should be considered.

These regional differences may be found at different levels. For example, at national level, the implementation of EU legislation may differ or some marketing channels may be of greater importance than others, e.g., if organic production is mostly exported. Furthermore, some types of organizational models for breeding in organic farming may be more common in some regions than in others (e.g. decentralized farmer-breeder networks in Southern Europe). These aspects need to be identified and incorporated when the pool funding is extended to a new region, e.g., Eastern Europe.

Over the last decades, there has been a reluctance to invest in organic breeding and seed multiplication (Döring et al. 2012). The proposed strategy should also contribute to overcoming this lock-in and facilitate more investment. There is a risk that the most aware actors do not compromise for a long-term, substantial financial commitment assuming that other firms would not join (Ostrom 1998). In a long-term perspective, all actors in the organic value chain can substantially benefit from investments in organic breeding and seed multiplication. However, 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. The increasing consolidation and dependence on few multinational breeding and seed companies and increased applications of new breeding techniques not in line with organic principles might result in increased consumer demand for organic from seed to fork. Consumers' expectation and buying behavior can have a significant impact on setting priorities for the organic value chain, as our results from the analysis of farm survey data suggest. In order to promote acceptance of a pool funding concept for organic breeding, the other key framework conditions must be met, and the background measures for facilitating collaboration along the value chain put in place. The most important aspects are a clear definition of how funds would be distributed, how the breeding needs and milestones for fulfillment would be determined (according to which rules) and how the property rights of produced cultivars would be managed. Transparent communication and decision structures will have to be established along with the commitment of market players to provide financing resources. Regarding the last aspect, ensuring that the financial burden is not shifted back to other value chain actors is crucial. In Germany, a pilot project began in 2020 to further elaborate and implement such a pool funding model under the guidance of the federal association of organic food industry (BÖLW).

To overcome the organic seed shortage, it is often argued that a phasing out of the derogations would be a sufficient market stimulant. However, earlier attempts at phasing out derogations of non-organic seed either resulted in a severe shortage of organic propagation material and the subsequent need to re-introduce the derogation regime. For example, derogations for juvenile fish in EU organic aquaculture were phased out in 2018 without a sufficient reaction of juvenile fish producers, resulting in a severe shortage of organic juvenile fish (Personal communication with Timo Stadtlander, an organic aquaculture expert). For organic seed in the EU, this was attempted in 2004 and then extenuated into promoting measures at country level as a first step, because a seed shortage was anticipated. Since then, the area organically farmed in Europe has increased dramatically, while the organic seed market has not grown at the same pace, resulting in an increased number of derogations in many countries for many crops (Solfanelli et al. 2019). Hence, the mere phasing out of derogations may not necessarily stimulate seed production enough. On the other hand, this example shows that there is a high level of political insecurity, as policy measures announced by the European commission are not necessarily implemented. This is likely to stop seed producers to invest into organic seed early. Furthermore, this study shows that finding sustainable solutions for an independent organic seed sector seems to include breeding activities targeted at the organic sector, as seed production and breeding are strongly interlinked.

The insights into the effect of value chains organization on current organic seed use back up the need for a pool funding model in the following ways. Firstly, there seems to be an urgency to increase awareness and involve processors, traders, and retailers when developing interventions to increase organic seed and cultivar use: Organic farmers embedded in short value chains use more organic seed compared to farmers using long value chains for marketing their produce. This outcome shows that farmers with closer contact with their end-consumer deem organic seed as an integrity attribute of organic farming. As most organic produce is, however, marketed through long value chains, targeting these value chains is of substantial importance when aiming at increasing organic seed use (Willer and Lernoud 2019). There is further evidence in literature that collaboration in prevailing organic value chains is low, and that the functioning of organic value chains is increased where there is a high level of collaboration and trust, as well as a cost and benefit sharing between value chain actors (Naspetti et al. 2011).

Secondly, the fact that farmers, especially those marketing through longer value chains, stated that the higher organic seed price is prohibitive for organic seed use, shows that the traditional financing strategy of breeding is challenged in organic agriculture. Depending on the crop, organic farmers use 8% to 28% farm-saved seed (Solfanelli et al. 2019) as they have difficulties affording the high priced seed. Thus, a change in attitude and behavior of downstream value chain actors toward supporting organic seed use and organic breeding may be necessary.

Thirdly, organic farmers in Europe, independently from their market channel, advocate for more investment in organic breeding to increase the use of organic seed, as opposed to only phasing out derogations. Thus, the goal of phasing out of derogations for non-organic seed in EU organic agriculture by 2036 (New Organic regulation 848/2018) is more likely to be achieved and to have a successful impact on the whole sector, if translated into an opportunity for implementing a sustainable and independent breeding sector. Therefore, two new types of cultivars, "organic heterogeneous material" and "organic varieties suitable for organic production", are promoted in the New Organic Regulation. Both should contribute to enhanced genetic diversity, disease resistance or tolerance and adaptation to diverse local soil and climate conditions while providing cultivars adapted to the principles and practices of organic farming.

Our findings regarding the influence of marketing channels on organic seed use are in line with former research, indicating that longer chains negatively impact organic seed use (Le Doaré 2017; Levert 2014; Rey et al. 2013). The perception of organic seed as an essential element for maintaining organic farming integrity is supported by a survey conducted in the US, where the highest agreement of all farmers was obtained for this statement (Hubbard and Zystro 2016). The finding that a higher price of organic seed being an obstacle, especially for farmers marketing through long value chains, cannot be confirmed by other studies (Hubbard and Zystro 2016; Levert 2014). However, as the price difference does not count as a viable reason for receiving a derogation, farmers are likely to be hesitant to report it. Looking at breeding and more suitable cultivars as a solution for more organic seed use, farmers often mention a lack of suitable cultivars multiplied under organic conditions in other research (Bocci, Ortolani, and Micheloni 2012; Hubbard and Zystro 2016). These results highlight the link between breeding and multiplication and show that the problem of organic seed shortage is more likely to be solved when also including breeding activities.

As a conclusion, to increase the availability of organic cultivars suitable for organic production for meeting the vision of the new Organic Regulation, a strong organic breeding sector is needed. Our results indicate that organic seed use and farmers' belief that organic seed use is crucial for the integrity of the organic chain are less prevalent in long value chains than in short. Further, the organic seed price is perceived as a stronger obstacle in long chains. Thus, as long value chains prevail in European organic agriculture, an intervention where downstream value chain actors, especially those active in longer value chains, are actively involved in overcoming the organic seed and cultivar shortage seems advisable to stimulate the market from both the supply and demand side. There are successful case studies of value chain supported pool funding for organic breeding for individual crops and breeding initiatives. Still, no examples exist where such a collaboration model between organic breeders and food trade actors has been established at a larger scale, nor has the long-term impact been evaluated. Such an evaluation after the implementation of the model would be a valuable avenue for research in the organic seed and breeding sector.

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Appendix

Table A1: Descriptive statistics of farm level variables of the respondents of the farmer survey

Table A2: Covariate balance summary of standardized differences between the long and short value chain groups of the farmer survey before (Raw) and after (weighted) applying ipwra

Variables	**Total**	**Short value chain**	**Long value chain**
	mean (standard deviation)	**mean (standard deviation)**	**mean (standard deviation)**
Number of crops per farm	3.715 (1.42)	3.94 (1.36)	3.40 (1.44)
Geographical area	**n %**	**n %**	**n %**
Central Europe	309 41.1	202 46.4	107 33.8
Eastern Europe	130 17.3	69 15.9	61 19.2
Northern Europe	124 16.5	51 11.7	73 23.0
Southern Europe	189 25.1	113 26.0	76 24.0

Covariates	**Standardized differences**		**Variance ratio**	
	Raw	**Weighted**	**Raw**	**Weighted**
Gender of respondent (female = 1)	−0.25	0.07	0.78	1.06
Age of respondent (years)	−0.04	−0.08	1.32	0.92
(Age of respondent)^2	−0.004	−0.09	1.28	0.87
Farm size (ln[ha])	0.81	0.22	0.61	1.03
(Farm size)^2	0.661	0.223	0.903	1.02
Years since conversion to organic farming (ln[years])	0.01	0.02	0.82	0.79
(Certification duration)^2	−0.04	−0.04	0.80	0.81
Education of respondent:				
-Apprenticeship	0.14	−0.03	1.10	0.98
-College/university degree	−0.12	0.11	0.98	1.01
Received training	−0.09	−0.06	1.10	1.08
Crop specialization (% of vegetable area (on the remaining area, arable crops are grown)	−0.52	−0.05	0.82	1.03