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Factors Affecting the Use of Organic Seed by Organic Farmers in Europe

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Received: 10 September 2020; Accepted: 13 October 2020; Published: 15 October 2020

Abstract: The new European Organic Regulation 2018/848 has announced the phasing out of derogations for the use of untreated non-organic seed by 2036. However, the use of organic seed by organic farmers is currently limited. This paper aims to identify the factors affecting the use of organic seed. It is based on data collected from 749 organic farmers in 20 European countries, by conducting an online survey and using a network sampling. Results of the descriptive statistics and linear mixed models indicate that: (1) the situation of organic seed use is not consistent across geographical regions and crop sectors; (2) the use of organic seed is higher on farms selling directly to consumers than on those selling to supermarkets; (3) larger and more recently converted farms use less organic seed than established organic farms. In the second part of the paper, we analyse farmers' attitudes towards organic seed use. The structural equation model (SEM) suggests that the highest contribution to explaining intention to use organic seed comes from social norms, i.e., farmers' perception of societal expectations, particularly from the consumer and the organic certifier. Such expectations, if communicated in the public and political discourse, could stimulate the use of organic seed.

Keywords: Europe; linear mixed models; organic farmers; organic regulation; organic seed; structural equation model

1. Introduction

According to the European Regulation (EC) 834/2007, organic farming should be using organic inputs wherever external inputs are needed [1]. The implementing rules laid down in Regulation EC 889/2008 state that organic agriculture should use seed obtained by the organic production method [2]. According to the Regulation (EC) 834/2007, European countries are required to list the varieties for which organically produced seed is available in the market on a national database. Still, the Regulation (Article 45) currently allows the use of untreated non-organic seed or seed potatoes through derogations where no organic seed is available. Authorisation for the use of untreated non-organic seed is an exception to the rule. It can be granted for one season at a time to individual

farmers, who can demonstrate that organic seed is not registered on the mandatory national organic seed databases for the varieties they want to use or cannot be delivered before sowing time. A Member State can also grant a general authorisation for all farmers if no sufficient seed is available in its territory for the given species or variety [2]. The new European Organic Regulation 2018/848 that will enter into force in 2022 has announced the phasing out of derogations in the EU organic agriculture by 2036 [3]. However, at present there seems to be still relatively limited use of organic seed [4,5].

Therefore, understanding why many organic farmers are not using organic seed becomes critical for the effective implementation of the Regulation and the phasing out of derogations.

The purpose of the research presented in this paper is to understand the underlying reasons for using or not using organic seed in European organic agriculture from a farmer's perspective. The study is based on an online survey with organic farmers, conducted in 2018–2019 with a sample of 749 organic farmers from 20 European countries who completed the survey, including countries from East Europe (Bulgaria, Hungary, Latvia, Poland, Romania), Central Europe (Austria, Belgium, France, Germany, Luxemburg, the Netherlands, Switzerland), Northern Europe (Denmark, Ireland, Sweden, the United Kingdom), and Southern Europe (Greece, Italy, Portugal, and Spain).

The review of previous literature summarised in Table 1 indicates a lack of recent research, addressing the issue of organic seed use at European or international level and for all the crop sectors. Six studies were found which are focused on some European countries [4,6–10], three on the US [9–11], and one study on Canada [12]. Four of them were based on surveys with organic farmers [6–8,11]. The other studies were based on policy analysis and surveys with seed companies and certification bodies [4,9,10,12]. Organic seed availability in relation to varietal choice, price, and quality, as well as regulatory barriers are the main factors found to have a potential role in the farmer's choice of organic seed. For example, the studies in France, Italy, and the US claim that seed price does not represent an important reason for not using organic seed, whereas the limited range of varieties available as organic seed represents a barrier to organic seed use [6–8,11]. Rey et al. (2013) [7] and more recently Le Doaré (2017) [8] found that organic vegetable growers in France tend to use more non-organic seed if they operate in long food supply chain compared to growers in short supply chains. From the farmer survey in the US [11], it emerged that the organic seed use across all crop types decreases as farm size increases.

Table 1. Summary of approach and key findings of previous studies on organic seed (OS).

Authors	Country	Method	Key Findings
Döring et al., 2012 [4]	Europe	Analysis of policy documents	Current derogation system is a barrier to the development of the OS sector
Bocci et al., (2012) [6]	Italy	Survey with 250 farmers	The main reason for not using OS is its availability for only a limited number of varieties
Rey et al., (2013) [7]	France	Survey with 720 vegetable growers	More OS is used by farmers operating in short supply chains and by established organic farmers rather than recently converted farmers
Le Doaré (2017) [8]	Bretagne (France)	Survey with 103 vegetable growers	More OS is used by farmers operating in short supply chains
Merfield (2012) [9]	International	Analysis of policy documents	Current derogation system is a barrier to the development of the OS sector
Renaud et al. (2016) [10]	US, Europe	Survey with seed companies, farmers, regulators, analysis of policy documents	Poor seed quality is a barrier to the development of the OS sector. Regulatory framework for OS in the U.S. is more fragmented than the European
Hubbard (2016) [11]	US	Survey with 1365 farmers, certifiers, and seed companies	Limited availability of OS in terms of variety choice and quantity is the main reason for not using OS
Levert (2014) [12]	Canada	Survey with 33 organic field inspectors	High price and limited quantity available prevent more use of OS

Given the scope of the Organic Regulation 2018/848 aiming for 100% organic seed for all crops and all Member States, our research has two main objectives. The first is to understand how organic seed use is affected by geographical region, crop sector, as well as other structural characteristics at

the farm level, such as farm size and marketing channel used. The second objective focuses on the attitudinal aspects relevant to farmers' decision-making process. According to Greiner and Gregg (2011) [13] and Adnan et al. (2019) [14], the study of farmers' decisions regarding agricultural practices requires good understanding of their individual and intrinsic motivations. Previous studies showed that farmers' psychological attributes or "psychographics" play a significant role in influencing their decisions, which are not only driven by the goal of profit maximisation [15–21]. This is relevant when it comes to the use of inputs like seed, especially in a sector like organic agriculture which is inspired by principles of health, ecology, fairness, and care [22]. The Theory of Planned Behaviour (TPB) [23] and the Technology Acceptance Model (TAM) [24] are amongst the most influential theoretical frameworks in social psychology, and were used in this study to understand the determinants of the use of organic seed by organic farmers. A structural equation model was used to determine the role of farmers' beliefs on the use of organic seed.

The paper is structured as follows. The next section describes the data collection and analysis approach. The results are presented in two main parts: structural factors affecting organic seed use, and the attitudinal aspects including the structural equation modelling. A discussion and conclusion section closes the paper.

2. Materials and Methods

2.1. Data Collection

To prepare the survey, we firstly conducted a literature review based on a search of the internet database Scopus, using a combination of key words related to organic seed and organic farming including: organic, seed, breeding, variety, cultivar, seed saving, farm-saved seed, organic regulation, derogation, seed quality, seed borne disease, seed germination, seed availability, seed price. Secondly, we carried out explorative semi-structured interviews with 11 organic farmers growing arable, forage, and vegetable crops in Germany (two interviews), Italy (two interviews), the Netherlands (one interview), and the United Kingdom (six interviews). This explorative stage helped us identify the key issues related to organic seed from the farmer's point of view. The survey was translated in 14 languages and pre-tests were conducted with farmers in Italy, Switzerland, and the UK. Finally, the survey was launched online in November 2018 and closed in June 2019. The survey was promoted by national organic associations and the partners of the EU-H2020 project LIVESEED, applying network sampling in each country. This was the only real option to collect data for two main reasons. First, despite the existence of registers of organic farms in all European countries held by certification bodies, these could not be used by the researchers for random selection due to concerns about Data Protection of the control bodies [25]. Second, farmers are, in general, not so willing to participate in surveys and they agree to participate only if this is recommended by someone whom they trust, such as farmer associations or certification bodies [21]. Therefore, the research project partners in each country were responsible for promoting and circulating the survey to organic farmers making use of their contacts with organic associations and certification bodies. While this approach to sampling resolves the data accessibility issue, the resulting sample cannot be considered representative of the population of organic farmers of the respective countries. While the intrinsic limitations of non-probability sampling method are well known, research has shown that results from non-probability samples are at least as good as than probability-based samples when appropriate techniques are employed to overcome its limitations [26].

The survey was administered online using the questionnaire platform Qualtrics. In Bulgaria and Greece, where farmers have lower access to the internet than in other European countries, the project partners conducted the survey over the telephone and entered the answers online. Table 2 below describes the characteristics of the sample.

Table 2. Socio-demographics and structural farm characteristics of the sample.

Variables			Sample
Age	**Years**	**Mean**	**47**
		S.D.	**11.9**
Sex	Female	%	29
	Male		71
	No		26.3
Farm size	Ha	Mean	79.8
		S.D.	164.3
Marketing channels	Direct to consumers	%	56.4
	Organic shops		23
	Cooperatives		31.8
	Processors/traders		40.6
	Supermarkets		8.7
Production orientation	Arable	%	40
	Vegetables		32
	Fruit		19
	Forage/livestock		9
European region	Central	%	41
	Eastern		23
	Northern		11
	Southern		25
Main seed source	Seed company	%	67
	Farm-saved seed		26
	Public seed agency		2
	Other		5
Total completed survey			749

Overall, 1475 accesses to the survey were recorded, of which 755 responses were completed. Six farms certified before 1978 appeared as outliers from a distribution with extremes set at 1.5 times the range between 1st and 3rd quartile and were removed; 749 completed surveys were retained in total.

The farm production orientation (PO) identifying the main crop sector of the farm was determined by multiplying the crop area provided by the respondents by the Standard Output coefficients for each crop in the considered countries, which is provided by Eurostat [27].

Given the relatively limited number of responses per country, we present and analyse the data by European geographical region rather than individual country, i.e., East, Central, Northern, and Southern Europe.

2.2. The Questionnaire

The questionnaire was structured in the following three main parts: (1) farmer and farm characteristics, (2) attitudinal statements, and (3) organic seed use for a selected number of species grown on the farm as a response variable. The 20 crops included in the survey (see Appendix A and Appendix B) were carefully selected with the support of LIVESEED project partners, based on their relevance in terms of land area and economic value in the countries involved (for details see [28]).

The first questions were about the socio-demographic profile of the farmer and farm characteristics, e.g., crops grown, farm size, location, time since conversion to organic agriculture, main seed supplier used. As marketing channels respondents were allowed to indicate up to three options amongst supermarkets, specialised organic shops, cooperative, processor, trader, and directly to consumers. The second part of the survey included attitudinal statements or latent constructs that the respondent was asked to assess on a five-point Likert scale from "strongly disagree" to "strongly agree", carefully chosen based on the literature and the exploratory interviews. Multiple items including between three and four statements were used to measure the latent constructs derived from the Theory of Planned Behaviour (TPB)—social norms and perceived behavioural control—and from the Technology Acceptance Model (TAM)—perceived usefulness [23,24,29]. Following Ajzen [23] and Davis [24], we also included in our model attitude, intention, and actual behaviour to organic seed use. Based on the criteria recommended by Fuchs and Diamantopoulos (2009) [30] for the use of single-item measures, attitude and intention were

measured with one statement for parsimony. The statements are presented in Table 3 in the results section.

In the third part, the respondents were also asked to provide an estimate in percentage of the organic seed used in the previous year per each crop grown on their farms. These percentages were then used to estimate the average percentage of organic seed use per farm. The questions of the survey used for this paper are provided in Appendix A.

2.3. Data Analysis

The survey was analysed in terms of how organic seed use changes and is affected by (1) geographical area and production orientation, (2) farm characteristics, and (3) farmers' attitudes and beliefs.

To understand differences among different groups of the sample, we analysed organic seed use by farm production orientation (PO), by European region, and by PO within each region through the non-parametric Kruskal–Wallis test with Bonferroni adjustment of *p*-value.

Subsequently, organic seed use was analysed through linear mixed models assuming the European geographical region as a random intercept and PO within EU area as a random slope [31], following three paths of investigation to understand the effect of farm size and year of certification; market channels, and seed supplier.

To analyse the effect of farm size and year of certification, stepwise addition of fixed terms was conducted in the following order: (i) a null model; (ii) log-transformed farm size; (iii) certification year, and (iv) the interaction between log-transformed farm size and certification year. Models were first fit through a maximum likelihood test and each model was compared against the previous one considering a significantly lower Akaike Information Coefficient (AIC) as a determinant of better fit. The significance of each fixed term was determined as comparison between the model containing the effect and the model not containing the effect. The best fitting model was then run through Restricted Estimated Maximum Likelihood (REML) and its quality of fit checked visually through quantile-quantile plots.

To analyse the effect of the different market channels, models with each market channel as fixed terms were fit through maximum likelihood and compared against the null model. The market channels individually resulting significantly better than the null model and their interactions were subsequently stepwise added to build a comprehensive model series, where each model was compared through maximum likelihood against the previous. The best fitting model was then fit through REML.

The effect of the use of different seed suppliers was simply addressed by comparing the model containing seed supplier as a fixed effect against the null model through a maximum likelihood test, and subsequently fitting the model through REML. For models with categorical fixed effect, estimated marginal means with Kenwar-Roger method for degrees of freedom and Tukey adjustment for *p*-values were calculated.

We used R version 3.6.1 "Action of the Toes" [32] on a platform: x86_64-w64-mingw32/x64 (64-bit). The package "agricolae" [33] was used for post-hoc tests and non-parametric analyses. The packages "lme4" [31] and "lmerTest" [34] were used for mixed-effect models. The package "emmeans" [35] was used to calculate estimated marginal means. Graphs were obtained through the packages "ggplot2" [36] and "jtools" [37].

The attitudinal part of the survey was analysed by a descriptive analysis followed by a Structural Equation Modelling (SEM) [38]. For the analysis, the items measured on the 5-point Likert scale were weighted 1 to 5 with higher values indicating greater agreement. Measurement reliability and validity were evaluated through Cronbach alpha and maximum likelihood confirmatory factor analysis. Cronbach alpha values are usually considered satisfactory if above 0.7, although values between 0.7 and 0.6 are also deemed satisfactory [39,40]. To evaluate the fit of the structural equation model, the following diagnostic indices were considered: the maximum likelihood X^2 value together with the degrees of freedom, the Root Mean Square Error of Approximation (RMSEA), the Comparative Fit Index (CFI), Ticket-Lewis index (TLI), and Root Mean Square Residual (SRMR). In

line with [40,41], the following standards for assessing models were followed: RMSEA ≤ 0.08, CFI ≥ 0.95, TLI ≥ 0.90, SMSR ≤ 0.08. We then tested model invariance to establish whether the psychographic characteristics of the measures were stable across the farmers operating in the four crop sectors and in the four geographical areas in Europe. Following the procedure recommended by Acock (2013) [42], we firstly tested the configural invariance model to see whether the same items measure our constructs across the groups of farms of different sectors and regions. Then we tested whether the constructs have the same meaning to participants across different crop sectors and geographical areas, i.e., the metric invariance model. We finally tested whether residual errors are equivalent across the groups of farmers. This procedure allows comparing models statistically using the difference in the X^2 statistics, degrees of freedom, as well the goodness-of-fit parameters RMSEA and CFI. Finally, in order to test whether the pairwise differences were significant, post-hoc multiple comparisons (Tukey HSD) were conducted between geographical regions and crop sectors. The attitudinal analysis was conducted by Stata, version 16.0 on a platform x86_64-w64-mingw32/x64 (64-bit).

3. Results

3.1. Farm Structural Characteristics: Descriptive Analysis and Multilevel Modelling

The difference in organic seed use is significant amongst European geographical regions ($p < 0.0001$). Farms in Northern and Central regions showed the highest values, with 80.8 ± 1.4% and 74.8 ± 3.3%, respectively. Intermediate values were found in farms in the Southern region, with 63.4 ± 2.7%. The lowest values were found in the East, with 51.6 ± 4.2%. Significant differences emerged among the different POs as well ($p < 0.0001$), with top values in the vegetable sector (75.8 ±1.8%), followed by the arable (70.0 ± 1.9%), the forage (65.7 ± 2.6%) and, lastly, the fruit sector (57.2 ± 3.3%) (Figure 1). The effect of PO within each area was only significant in Southern Europe, where the use of organic seed resulted to be higher in the vegetable than in the fruit sector.

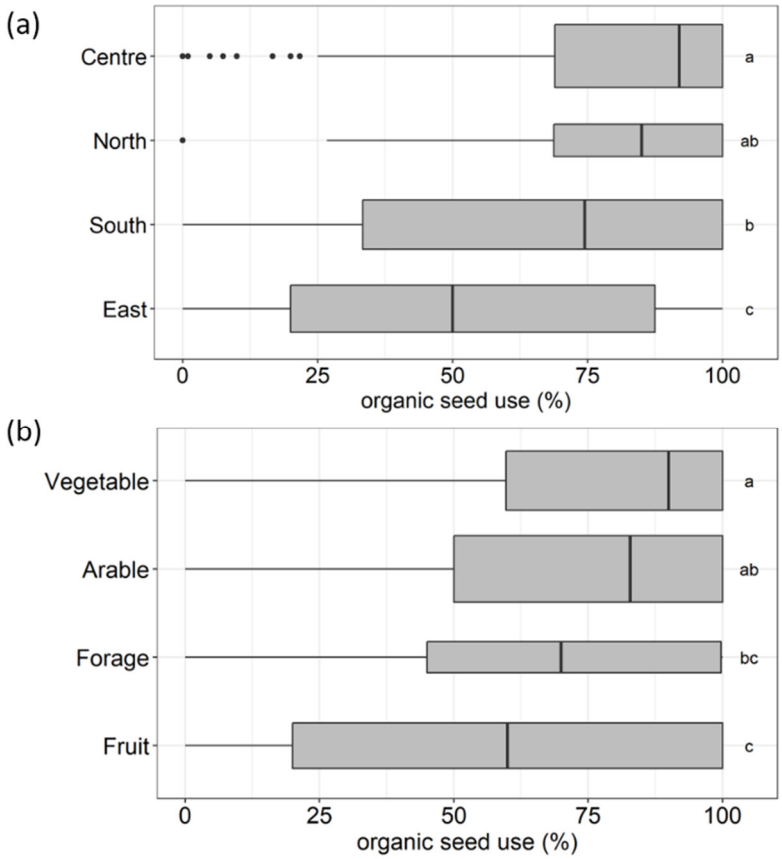

Figure 1. Percentage of organic seed used by European region (**a**) and production orientation (PO) (**b**). Vertical lines indicate the group's median, boxes represent group's interquartile range, whiskers

extend to 1.5 the interquartile range. Boxes width is proportional to the number of responses of the group. Groups with the same letter are not significantly different according to the Kruskal–Wallis test with Bonferroni p-value adjustment, with a 0.95 confidence level.

Assuming European region as a random intercept and PO within region as a random slope, the best fit model explaining the effect of farm size and year of certification was the one considering both these terms and their interaction (Table A1 in Appendix B). With 65.3% of the total variation explained by these fixed terms, this model suggests that:

- The use of organic seed decreases linearly with increasing farm size (t = 2.48, $p = 0.0134$).
- There is no significant effect of certification year on organic seed use (t = 1.276, $p = 0.2025$).
- However, certification year interacted with farm size, with a steeper decrease in organic seed use in more recently converted farms (t = −2.514, $p = 0.0121$) (Figure 2a).

Out of the six market channels considered by the survey, a significant effect on organic seed use was found for direct selling to consumers (AIC = 7293, $X^2 = 31.58$, $p < 0.001$), supermarket (AIC = 7227, $X^2 = 97.36$, $p < 0.001$), organic shop (AIC = 7319, $X^2 = 5.618$, $p = 0.0178$), but not for "cooperative," "processor," or "other." Considering that the survey allowed to indicate up to three marketing channels, the best fitting model was the one considering the additive effect of "supermarket," "consumer," "organic shop," and the possible interactions thereof (Table A2 in Appendix B). With 71.4% of the total variance explained by the fixed effects, this model suggests that:

- Farms selling to supermarket have a 45.4 ± 4.8% lower rate of organic seed (in absolute terms) than farms who do not (t = −9.354, $p < 0.001$) (Figure 2b).
- Farms practicing direct selling to consumers have an 8.36 ± 2.56% higher (in absolute terms) rate of organic seed use than farms who do not (t = 3.338, $p = 0.0009$).
- Having an organic shop amongst other market channels does not significantly affect, on its own, the use of organic seed (t = 0.898, $p = 0.370$). However, among farms who sell to supermarkets, those selling also to organic shops have an 11.35 ± 10.17% higher rate of organic seed use (in absolute terms) than farms who do not (t = 2.364, $p = 0.0183$).

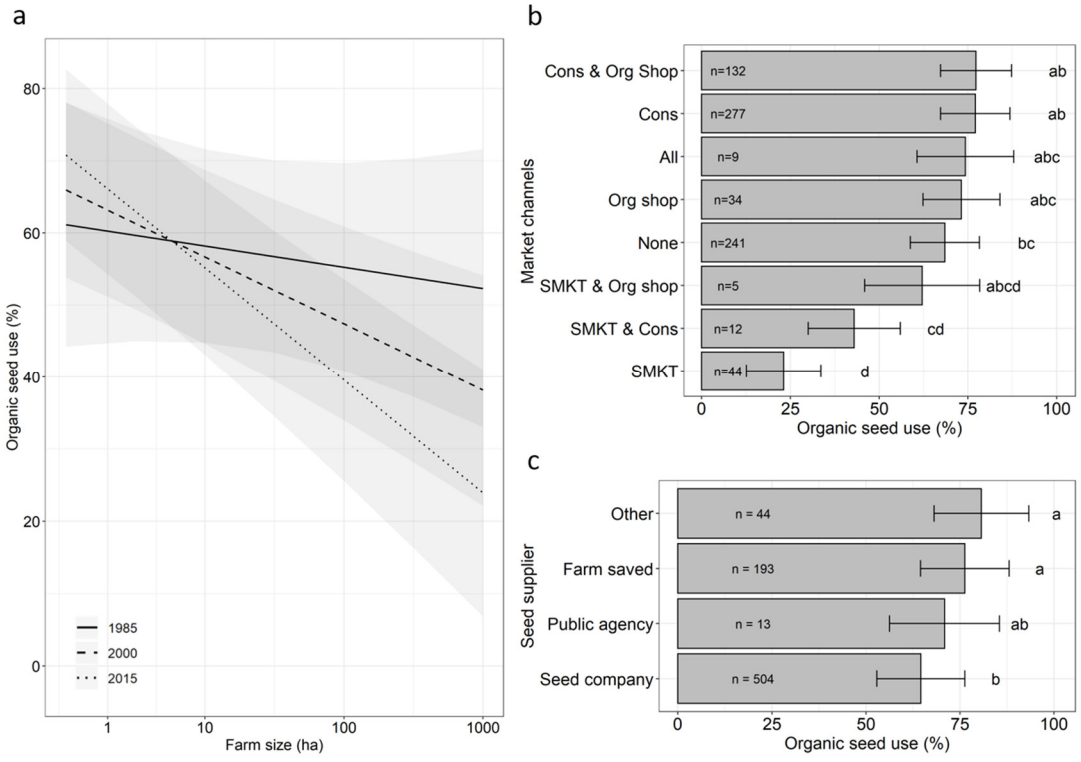

Figure 2. Effects of farm characteristics on organic seed use. (**a**): Effect of farm size and farm certification year. Marginal estimated effect and 95% confidence intervals, as resulting from linear

mixed-effect models assuming farm size (log-transformed), year of certification and their interaction as fixed terms, EU area as a random intercept, and crop sector within EU area as a random slope. Three illustrative levels of "year of certification" are shown. (**b**): Effect of market channel on organic seed use. Estimated marginal means and standard errors of organic seed use by product market channel: "Cons" = direct selling to consumers; "Org Shop" = Organic shop; "SMKT" = Supermarket; "None" = other than direct selling to consumer, organic shop or supermarket; "All" = Selling through all marketing channels. (**c**) Effect of main seed supplier on organic seed use. Estimated marginal means and standard errors of organic seed use by main seed supplier (source of more than 50% of the seed used on farm): "Farm saved" = "I use my own seed"; "Public agency" = "Public seed agency"; "Seed company" = "Seed companies/seed retailers"; Other = neither Farm-saved, Public agency, or Seed company. In charts (**b**,**c**), estimated marginal means with the same letter are not significantly different (Kenwar-Roger method for degrees-of-freedom and Tukey p-value adjustment for a 95% confidence level). Numerosity of the group is indicated in each bar in (**b**,**c**).

There was a significant difference in organic seed use for those respondents indicating seed companies (65.0%) as main seed source compared to those using farm saved seed (76.7%) or others (81.0%) (Figure 2c).

3.2. Attitudinal Aspects: Descriptive Analysis and Model Validation

The statements relating to attitude and intention (Table 3) to use organic seed showed a good level of agreement amongst farmers, with more than 60% of the respondents who "strongly agree" or "agree" with the related statements provided.

Less agreement was found with the statements relating to the perceived conditions for using organic seed: the percentage of "strongly agree" with the four items is below 20%. Particularly negative is the assessment of the statement "Organic seed is easily available for the varieties that I want to use," with 33% of "disagree" and 15% "strongly disagree." The level of agreement with the statement "Price for organic seed is accessible" is below 30% of total responses. Overall, about 50% of the farmers either "agree" or "strongly agree" with the statement "Availability of organic seed has improved in the last five years." The best rate among the four items related to perceived conditions is with the statement on seed quality, with more than 50% of respondents who either "strongly agree" or "agree" with the statement "The quality of organic seed that I use in my farm is high."

Most respondents "strongly agree" or "agree" with the statements relating to the perceived usefulness of using organic seed, in particular with "Organic seed is important for the integrity of organic production" and "By using organic seed I support the competitiveness of the organic sector."

As for the items relating to "subjective norms," about 60% of respondents either "strongly agree" or "disagree" with the statement that their buyer would expect them to use organic seed, and that they are encouraged by their certifier to use organic seed. Lower and overall more neutral is the agreement with the statement that other farmers play a role in persuading them to use organic seed.

Cronbach's alpha internal reliability coefficients were acceptable, with values above 0.6, which can be considered the cut-off value [37,38]. Confirmatory factor analysis (CFA) was conducted on multi-item scales. As shown in Table 3 below, convergent validity is supported as all the standardised loadings are significant and in the correct direction.

Table 3. Latent constructs, items, descriptive statistics, and standardised factor loadings in the confirmatory factor analysis (CFA). Items are measured on a 5-point Likert scale where strongly disagree = 1, disagree = 2, neutral = 3, agree = 4, strongly agree = 5.

Latent constructs	Items	Mean	S.D.	Standardised Factor Loadings
Social norms	Other organic farmers have encouraged me to use organic seed	3.71	1.13	0.51 ***
	I am encouraged to use organic seed by my certifier	3.01	1.09	0.60 ***
	My buyer would expect me to use organic seed	3.73	1.10	0.71 ***
Perceived behavioural control	Availability of organic seed has improved in the last five years	3.40	1.05	0.60 ***

	Price for organic seed is accessible	2.76	1.11	0.45 ***
	Organic seed is easily available for the varieties that I want to use	2.74	1.18	0.71 ***
	The quality of organic seed that I have used on my farm is high	3.58	0.96	0.50 ***
Perceived usefulness	Organic seed is better suited to organic farming	3.74	1.17	0.73 ***
	Organic seed is an important part of maintaining the integrity of organic food production	4.21	0.94	0.82 ***
	By using organic seed, I support the competitiveness of the organic sector	4.03	1.01	0.71 ***
Attitude	I am positive about using organic seed	4.28	0.85	-
Intention	Next year I intend to use organic seed for all the organic crops on my farm	3.77	1.23	-

*** $p < 0.001$

All possible relationships between latent constructs were tested (Figure 3). As a result, significant and strong relationships emerged (i) between social norms and intention, (ii) between intention and behaviour, (iii) between perceived usefulness and attitude. The relationships between attitude and intention and between perceived conditions and behaviour also resulted positive and significant but of relatively low strength. Whether or not the model was an adequate fit was assessed using the diagnostic indices. The final measurement model showed a close fit, with $X^2(47) = 133$, $p < 0.001$; RMSEA = 0.05; CFI = 0.97; TLI = 0.96; SRMR = 0.02.

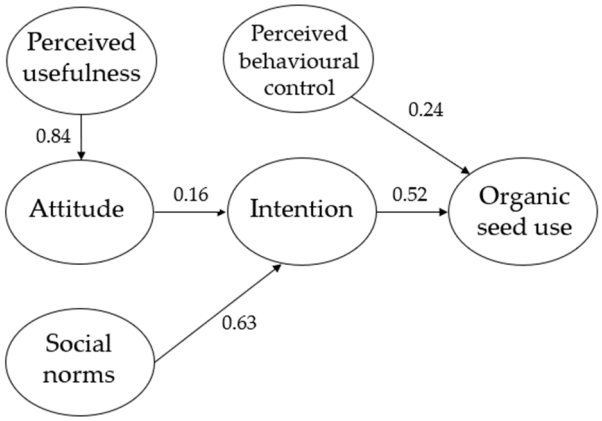

Figure 3. Final estimated model (standardised solution): X^2 (47) = 133, $p < 0.001$; RMSEA = 0.05; CFI = 0.97; TLI = 0.96; SRMR = 0.02. All path coefficients are significant at $p < 0.001$.

The measurement invariance analysis was performed to validate the model across different samples, specifically across POs and geographical regions. Goodness-of-fit statistics are presented in Table A3 and Table A4 in Appendix B. Although the X^2 is significant at every step, the RMSEA and CFI values indicate acceptable fit for all models. The RMSEA values for the models considering different European regions are above 0.06 but below 0.08, which can still be considered acceptable [41,42]. Overall, it can be concluded that the psychographic characteristics of the measures are invariant across the four POs and the four region-specific samples.

The means of the underlying constructs show some significant differences. As for the different POs, post-hoc multiple comparison tests indicate that differences in attitude, social norms, perceived usefulness, and perceived conditions are significant between the vegetables and the arable sectors, with the lowest values with the latter (Figure 4). Differences in latent constructs between geographical areas are significant in most cases (Figure 5). The attitude towards the use of organic seed is significantly lower in Eastern Europe than in Central and Southern Europe; Central Europe performs significantly better than the South and the North as well. External conditions are significantly better perceived in Central Europe than in East Europe and South Europe, and in the North compared to the East and the South. Perceived usefulness of organic seed use is significantly higher in the Centre than Eastern and Northern Europe, and it is significantly lower in the East than in the South. Social

norms are significantly lower in Eastern Europe compared to Central, Northern, and Southern Europe.

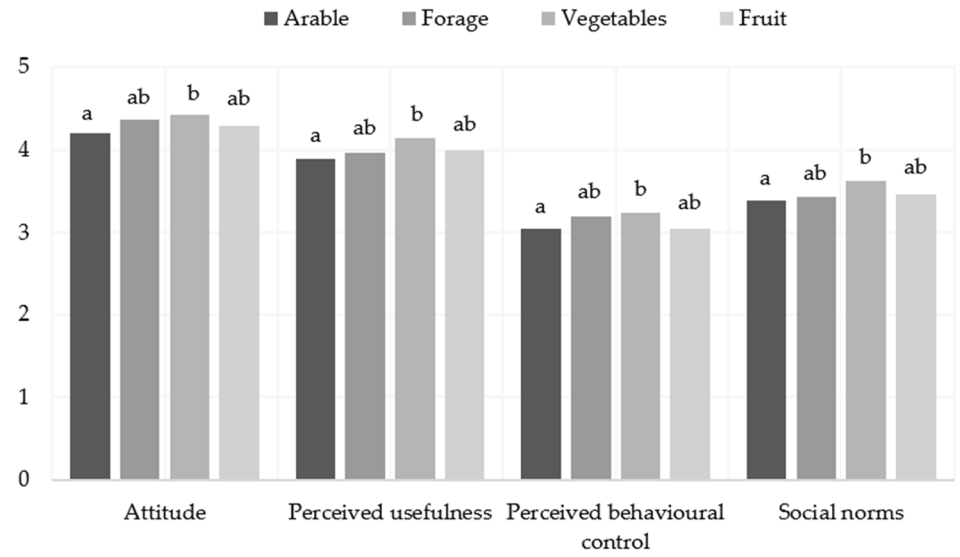

Figure 4. Latent variable means by farm production orientation. Groups with the same letters are not significantly different according to Tukey test (items are measured on a 5-point Likert scale where strongly disagree = 1, disagree = 2, neutral = 3, agree = 4, strongly agree = 5).

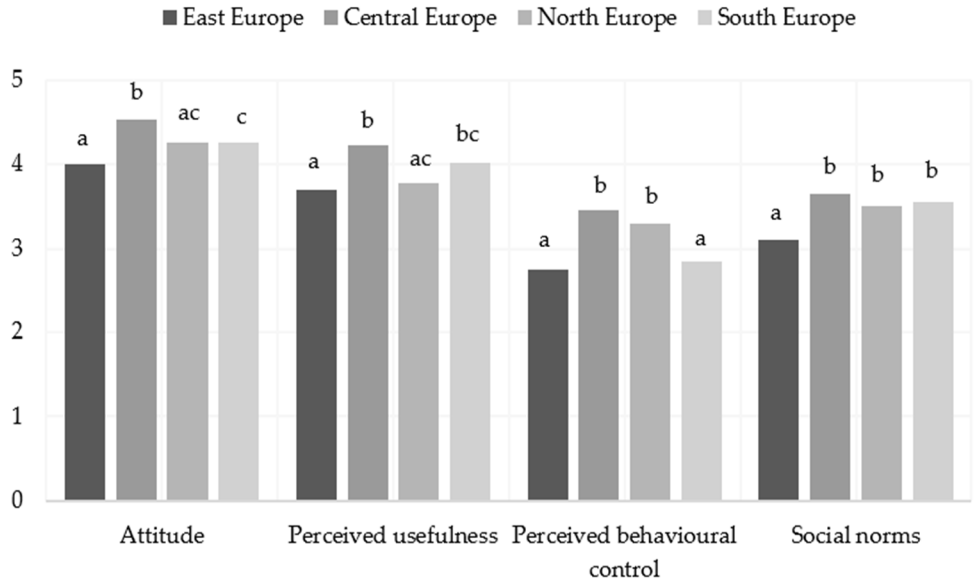

Figure 5. Latent variable means by European geographical region. Groups with the same letters are not significantly different according to Tukey test (items are measured on a 5-point Likert scale where strongly disagree = 1, disagree = 2, neutral = 3, agree = 4, strongly agree = 5).

4. Discussion and Conclusions

In this study, we have identified a number of structural and attitudinal factors affecting the use of organic seed by organic farmers in Europe through a survey with 749 organic farmers. To the best of our knowledge, this is the first study investigating organic seed use from the farmer's point of view in several European countries and taking into account all crop sectors. However, the findings have to be interpreted with some care because of the use of network sampling.

Our survey indicates that the situation of organic seed use is not consistent across European geographical regions and crop sectors. In fact, farms in the Northern and Central regions showed significantly higher organic seed use rate than farms in South and East Europe. Top values were found in the vegetable sector, followed by the arable, the forage, and the fruit sector.

The use of organic seed is higher on farms selling directly to consumers than on farms selling to supermarkets, which is in line with two previous French studies in the vegetable sector [7,8]. This poses a real challenge to the organic sector, as most of the organic food in Europe is sold through supermarkets [43,44]: 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 specialised organic supply chains. Our findings also indicate that larger and more recently converted farms tend to use organic seed to a lesser extent than established organic farms. This is also in line with studies conducted in France [7] and the US [11], which claimed respectively that farmers tend to remain faithful to the varieties used prior to conversion, and that organic seed use decreases as farm size increases. As more and more farms in Europe convert to organic farming [43], it is critical to the effective implementation of the new European Organic Regulation 2018/848 that the use of organic seed becomes a practice adopted also by the new generation of organic farmers. This requires that on the one side organic seed production needs to be strongly promoted and on the other side authorisation for non-organic seed are not easily granted to avoid market distortion. Very detrimental to the goal of 100% organic seed is the common practice in some Member States of general derogation for non-organic seed for a very large range of crops species.

The attitudinal part of this research has some theoretical and some practical implications. The main critical issue reported by the farmers in our study is the availability of organic seed for the varieties they need, which was indicated also by organic farmers surveyed in 2010 in Italy [6] and in 2014 in the U.S. [11]. In our survey, this is true regardless of the crop sector, but it is significantly less pronounced in the countries in Central and Northern Europe, where most organic seed production in Europe takes place [45]. Based on the structural equation model, we found that the association between use of organic seed and perceived conditions—i.e., perceived availability of organic seed varieties, as well as perceived quality and price—was significant although relatively weak.

The surveyed farmers have a positive attitude towards organic seed use. Although attitudes may not automatically lead to actual behaviour, farmers are more likely to develop a positive attitude towards the use of organic seed if they perceive it can contribute to the organic sector as a whole, especially in terms of supporting the integrity of organic food production.

The highest contribution to explaining the intention to use organic seed across the whole sample comes from social norms. Previous literature offers mixed results about whether social pressure is associated with farmer's intention to adopt recommended practices [46–49] or has marginal or no contribution at all [21,50,51]. Our result is not fully unexpected given that the participants of our survey were organic farmers, who are often driven by social and moral concerns [46].

Overall, the key outcome of the structural equation model is that farmer's beliefs and intentions related to the use of organic seed are mainly shaped by his or her perception of societal expectations, in particular from the consumer or the organic certifier. One important implication is that these expectations, if communicated in the public and political discourse, can stimulate the use of organic seed. It becomes critical then for the competitiveness of the organic sector that stakeholders, including seed companies and public decision makers, invest in providing good quality seed for the varieties that organic farmers need. In order to allow all European farmers to pursue the inter- and intra-species diversity required in organic farming [52], it is paramount that a wide range of varieties suitable to different agri-environmental conditions is made available as organic seed throughout Europe.

Author Contributions: This study was based on the collective effort of all the Authors. S.O. wrote Sections 1 and 4; S.O. and A.C. jointly wrote Sections 2 and 3. S.O., A.C., F.S. (Francesco Solfanelli), and R.Z. analysed the data; S.O. and S.P. designed the survey with contribution of all the authors. M.M.M. initiated and supervised the project. All the authors contributed to the data collection and reviewed the paper. All authors have read and agreed to the published version of the manuscript.

Funding: This research was funded by the European Commission Horizon 2020 Research and Innovation programme through the project LIVESEED, under grant agreement No 727230, and by the Swiss State Secretariat for Education, Research and Innovation under contract number 17.00090.

Conflicts of Interest: The authors declare no conflicts of interest. The funders had no role in the design of the study; in the collection, analyses, or interpretation of data; in the writing of the manuscript, or in the decision to publish the results.

Appendix A. Survey Questions Used for the Analysis Presented in this Paper

- Please scroll down the list below and select the main crops that are grown at your farm and are certified organic:
  Barley/Grain maize/Oats/Soft wheat/Durum wheat/Soybeans/Lupine/Pea/Alfalfa/Forage mixture/Apple/Grape/Olive/Strawberry/Potato/Cauliflower/Carrot/Onion/Tomato*
  ** White clover/Red clover/Perennial ryegrass/Italian ryegrass/Red fescue/Tall fescue/Other.*
- Please indicate the country where your farm is based
- Please indicate your sex
- Please indicate the year you were born
- Please indicate the approximate size of your farm size in hectares
- In which year has your farm started being certified organic?
- Where do you sell your organic farm products? You can select up to the three most important selling channels:
  Directly to consumers (such as purchase groups, box schemes, community supported agriculture, farm shops)/Cooperative or producer group/Processor/trader/Specialised organic retailers/Supermarkets/Other.
- Where do you buy your organic or untreated conventional seed? Please select only the main supplier:
  Seed companies or seed retailers/Public seed agencies/I use my own seed/Other.
- Please indicate the approximate percentage (0 and 100) of organic seed (or propagation material) that you used the last time that you sowed/planted your organic crops.
- Please indicate the approximate land area in hectares of your organic crops at your farm last year
- To what extent do you agree with the following statements? Totally agree–agree–neutral–disagree–totally disagree:
  - *My buyer would expect me to use organic seed*
  - *I am encouraged to use organic seed by my certifier*
  - *Other organic farmers have encouraged me to use organic seed*
  - *Availability of organic seed has improved in the last five years*
  - *Price for organic seed is accessible*
  - *Organic seed is easily available for the varieties that I want to use*
  - *The quality of organic seed that I have used on my farm is high*
  - *Organic seed is better suited to organic farming*
  - *Organic seed is an important part of maintaining the integrity of organic food production*
  - *By using organic seed, I support the competitiveness of the organic sector*
  - *I am positive about using organic seed*
  - *Next year I intend to use organic seed for all the organic crops on my farm*

Appendix B. Data Analysis Results

Table A1. Effect of farm size, year of certification, and the interaction between farm size and year of certification on the percentage of organic seed used on farm. Linear mixed-effect models with progressively added fixed terms as fit by likelihood ratio test.

	Null Model	Farm Size (Log Transf.)	Year of Certification	Interaction
d.f. (1)	12	13	14	15
AIC (2)	7245.1	7220.1	7218.4	7215.5
X^2 (3)	-	27.04	3.704	4.883
p-value	-	<0.001 ***	0.0543 (*)	0.0271 *

(1): degrees of freedom; (2): Akaike's Information Criterion; (3): X2 of comparison of the model with the fixed term of interest against the model without the fixed term of interest; (*) $p < 0.1$; * $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$.

Table A2. Stepwise addition of the effect of supermarket (SMKT), direct consumer selling, selling to organic shop, interaction between supermarket, and direct consumer selling, and all possible interaction between the three market channels, on the percentage of organic seed used on farm. Linear mixed-effect models with progressively added fixed terms as fit by likelihood ratio test.

	Null Model	SMKT	Cons	Org Shop	SMKT × Cons	SMKT × Cons × Org Shop
d.f. (1)	12	13	14	15	16	19
AIC (2)	7245.1	7227.4	7210	7212	7204	7198
X^2 (3)	-	97.36	18.94	0.270	9.732	12.48
p-value	-	<0.001 ***	<0.001 ***	0.604	0.0018 **	0.0059 **

(1): degrees of freedom; (2): Akaike's Information Criterion; (3): X^2 of comparison of the model with the fixed term of interest against the model without the fixed term of interest; (*) $p < 0.1$; * $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$ 'Cons' = direct selling to consumers; 'Org Shop' = Organic shop; 'SMKT' = Supermarket.

Table A3. Comparison of models by Production Orientation.

Model	X^2(df)	RMSEA	CFI
Same form model	288(188) ***	0.05	0.97
Equal loadings model	316(209) ***	0.05	0.97
Equal loadings and errors model	384(272) ***	0.05	0.97

*** $p < 0.001$

Table A4. Comparison of models by European geographical region.

Model	X^2(df)	RMSEA	CFI
Same form model	402(188) ***	0.07	0.93
Equal loadings model	445(209) ***	0.07	0.92
Equal loadings and errors model	572(272) ***	0.07	0.90

*** $p < 0.001$

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