Final report

Temporary experiment providing for certain derogations for the marketing of populations of the plant species wheat, barley, oats and maize

(Decision 2014/150/EU)

Content

Abstract

Council Directive 66/402/EEC on the marketing of cereal seeds sets out requirements for the production and marketing of seed which prevent the marketing of seed of populations. In order to market seed of populations, this Directive would have to be adapted. Therefore the European Commission decided to conduct a “Temporary experiment providing for certain derogations for the marketing of populations of the plant species wheat, barley, oats and maize” (Decision 2014/150/EU) to clarify questions on the identification of populations and the traceability of the seed of populations.

Eight Member States participated in the temporary experiment which allowed the marketing of seed of authorised populations from 2014 to 2021. A total of 46 populations - mainly wheat (84%) - were authorised, seed was produced of 26 and marketed of 22 populations. In addition Italy carried out extensive trials on morphological characterisation to assess and define methods applicable for identification of populations. Germany conducted field trials with maize and wheat populations to assess yield potential, susceptibility to pests and diseases and further characteristics.

Italian results showed that populations are basically identifiable by using morphological characterisation and statistical methods. However, these methods are highly cost and time consuming. German field trials revealed that only population specific conclusions in regard to yield, quality and resistances should be drawn as the populations differ in these aspects.

In conclusion the temporary experiment revealed that the identification of populations cannot be ascertained in the context of regular field inspection and post control as applicable methods are too cost and time consuming and the intended adaption of populations results consequently in the loss of their initial identity. Field inspection can only evaluate health status, general crop appearance and contamination with other species. Seed identity can be ensured by specification of traceability requirements and a control system. Overall, on the example of wheat populations from several participating member states it can be concluded that the concept of populations works best when simultaneously networks and supply chains are developed.

1. Introduction and objectives

Prior to 2001 several wheat populations[1] were bred and tested either in field trials (2001 – 2006) or in a project[2] (2008 – 2012) – both funded by the Department for Environment, Food and Rural Affairs (Defra; United Kingdom) and industrial partners within the United Kingdom. The wheat populations showed to be more resilient than single varieties, had a greater capacity to buffer against adverse environmental conditions and diseases and were aimed at organic and low input production. The populations also displayed a higher yield than the mean of their parent varieties and a more consistent performance from year to year. These results were followed by a rising interest in commercialisation of cereal populations.

However, Council Directive 66/402/EEC on the marketing of cereal seeds sets out specific requirements for the production and marketing of seed. These requirements prevent the marketing of seed that does not belong to a variety. In order to market seed of populations, this Directive would have to be adapted. Thus, based on the results obtained between 2001 and 2012 the United Kingdom initiated a request for a temporary experiment to evaluate the necessary changes that need to be implemented in the Directive. The European Commission followed this request with a Decision to conduct a "Temporary experiment providing for certain derogations for the marketing of populations of the plant species wheat, barley, oats and maize" (Decision 2014/150/EU) to clarify the following questions:

a.) Can populations be identified based on information on their breeding and production method, the varieties used in the crossing and the main characteristics of the populations?
b.) Can the identity of seed from marketed populations be based on traceability requirements and identification of the production region?

The temporary experiment was restricted to the species wheat, barley, oat and maize, which account for a significant share of the cereal seed market and for which research results are available.

2. Participating Member States

At the beginning five Member States besides United Kingdom (UK) expressed interest in participation, namely Denmark (DK), France (FR), Germany (DE), Italy (IT) and Netherlands (NL). Latvia (LV) joined in 2018 and Hungary (HU) in 2019. Finally eight Member States took part in the experiment.

The leading Member State was initially UK. Due to Brexit the leader ship was transferred to DE in spring 2018.

[1] According to Decision 2014/150/EU populations are plant groupings which are a result from a given combination of genotypes, considered as units with regard to their suitability for being reproduced unchanged once established in a given region of production with specific agro- climatic conditions and generated by one of the techniques specified in Decision 2014/150/EU.

[2] https://www.organicresearchcentre.com/our-research/research-project-library/adaptive-winter-wheat-populations-development-genetic-characterisation-and-application/ (accessed 29.11.2021)

3. Set up of experiment

3.1. Populations

According to Decision 2014/150/EU populations authorised in the framework of the experiment needed to comply with the following requirements:

a) result from a given combination of genotypes
b) are considered as units with regard to their suitability for being reproduced unchanged once established in a given region of production with specific agro-climatic conditions
c) are generated by one of the following techniques:
   i. crossing five or more varieties in all combinations followed by bulking of the progeny and exposing the stock to natural selection in successive generations;
   ii. growing together at least five varieties of a predominantly cross-fertilising species, bulking the progeny, repeatedly re-sowing and exposing the stock to natural selection until plants of the original varieties are no longer present;
   iii. inter-crossing varieties using crossing protocols different from those in i or ii to produce a similarly diverse population that does not contain varieties

3.2. General data assessed

Article 17 and 18 of the Decision 2014/150/EU required the participating Member States to record and report information gathered during the experiment as well as to report the produced and marketed quantities of seed of populations. UK had designed a template to facilitate and harmonise the recording and reporting: This template was slightly amended in 2019 as further valuable aspects emerged with the progress of the experiment.

Data were yearly recorded on administrative aspects, general and specific aspects with regard to the populations used and also on information on public relations activities:

3.2.1. Administrative aspects

- no. of applications
- no. of authorisations
- no. of withdrawals
- no. of valid/living/active populations
- seed production and marketing of populations
- description of authorisation procedures
- costs for applicants

3.2.2. Populations – general aspects

- species
- denomination
- technique used for generating the population
- size of participating breeder and producer
- quantities of seed produced per population
- quantities of seed marketed per population
- seed destination
- type of production system (organic, conventional; since 2019)

3.2.3. Populations – specific aspects

- description of production process
- description of trials carried out
- results of field inspection and seed testing (achievement of C2 standard)
- general remarks (e.g. observed diseases, pests, weeds…)
- valuation of populations by users

3.2.4. Public relations activities

- field days, seminars, networking events for farmers, millers, bakeries
- information for consumers

3.3. Additional data assessed

IT and DE conducted extensive comparative field trials and delivered additional results working on the following questions:

- How to characterise populations to facilitate identification?
- How do populations perform in comparison to single control varieties?

4. Results

4.1. Administrative aspects

4.1.1. Number of applications, authorisations and withdrawals

The experiment facilitated the marketing of seed of populations of four different species: maize, wheat, barley and oat. In total the Member States received 52 applications and authorised 46 populations: five maize, three barley and 41 wheat populations. Thus more than 80% of the populations in the experiment were wheat populations (Figure 1). Figure 2 shows the number of populations per species and Member State. The highest number of authorised populations was reported for DE (22) and IT (16). All applications received in DK were withdrawn prior to authorisation including the only application within the experiment for an oat population. Authorisation was withdrawn by the breeders for seven populations in total – one in FR (2019), and six in DE (2020).

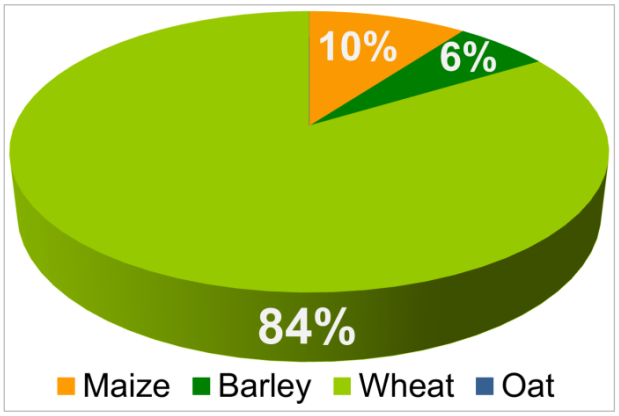

Figure 1 Proportion of plant species on all 46 authorised populations.

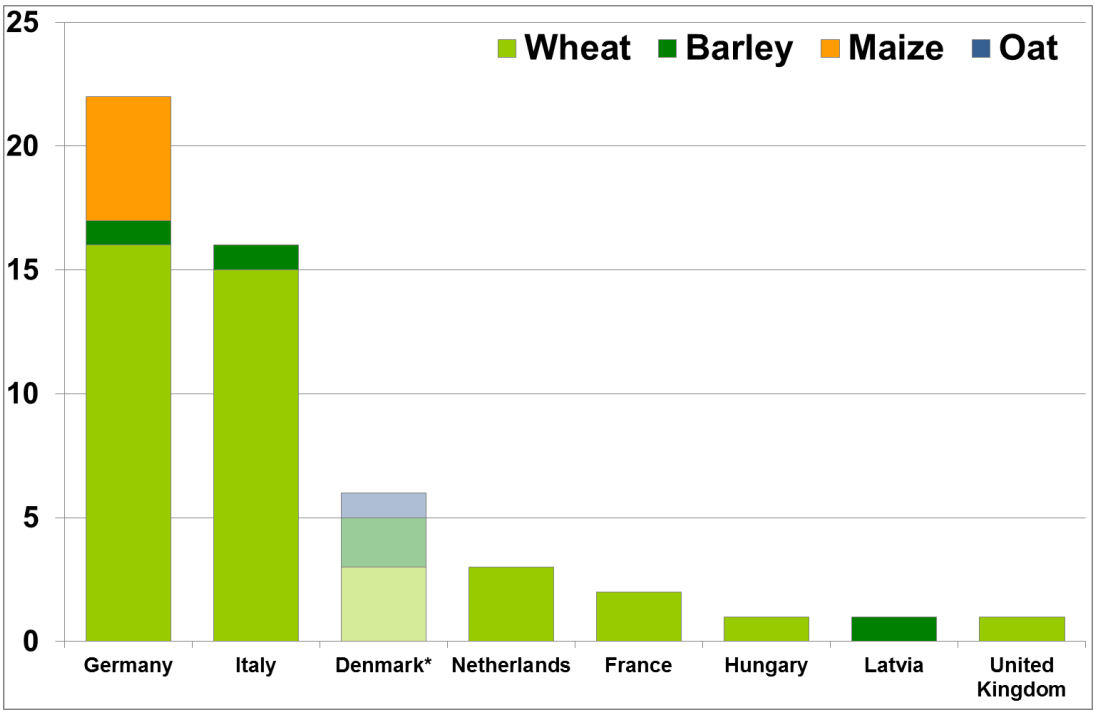

Figure 2 Number of authorised populations per member state and species.
* Applications existed but were withdrawn prior authorisation

4.1.2. Information on authorisation procedures and costs

The authorisation process differed between the eight participating Member States. Authorisation was given based on the compliance with the requirements of the Decision 2014/150/EU by either the Plant Variety Offices, Plant Protection Services or Certification Agencies. All participating Member States waived their fees for the application and authorisation of the populations. For field inspection and seed testing generally the normal fees were applied. Only FR did not charge any costs at all.

Table 1 Short descriptions of the authorisation process in the participating member states.

Member state	Authorisation process
DE	The completed application form must be sent to the Federal Plant Variety Office (Bundes-sortenamt, BSA). The denomination is published for at least 3 months prior authorisation. After authorisation, the regional certification and market control agencies are informed. Upon application the BSA also issues authorisations for the marketing of seed of populations.
DK	A written application with information according to 2014/50/EU had to be handed in.
FR	Request for authorisation and registration had to be handed in by the applicant to Service officiel de contrôle et de certification (SOC). SOC examined the application file including the elements of 2014/150/UE article 7.
HU	Breeder notified NDA by 28.02.2020.

Table 1 (*cont*.) Short descriptions of the authorisation process in the participating member states.

Member state	Authorisation process
IT	The applicant sent a request for participation in the temporary experiment to the Ministry for authorisation, which forwards it to the Commission. Subsequently, the applicant registers for field inspections at the Certification Agency (CREA DC) using the online system already available for varieties.
LV	In order to get an authorisation for population the applicant must submit an application to the State Plant Protection Service and a representative sample of the population. State Plant Protection Service checks the application and information according to the EU Decision, as well as they visit the producer in the production area. If the applicant has submitted all necessary information according to the EU Decision and the population and production area refer to the requirements of the EU Decision the application is authorised.
NL	Application to Plant variety office (Naktuinbouw) – approval of denomination – costs to applicant not applicable (costs subsidized by Board of Plant Varieties)
UK	Official checks on the authorised population are made to confirm the population description, field inspections are made and seed tests are carried out for the authorised population.

4.1.3. Development of seed market prices

A small survey carried out in 2021 between the MS on the development of the seed price for the seed of populations revealed a significant variation (Table 2).

The price for populations' seed in DE stayed stable during the experiment and was at a comparable level or only slightly above the prices for seed of varieties. In FR only one population was marketed in only one year. As only small quantities of seeds were available the price was 20% higher than the average prices for seeds of varieties organically produced and 80% higher than the average prices for seeds of varieties conventionally produced, respectively. In 2020 in LV prices for seed of population 'Mirga' had more than doubled compared to the previous two years as breeders aimed to equalize it with prices for category PB seed. In IT prices showed great variation between and within species. While prices within the different durum and soft wheat populations were stable over the four years, prices between them differed greatly from 70 to 180 €. For the barley population an increase from 12.5 € (2018) to 65 € per 100 kg of seed (2020) could be observed compared to a stable price of approximately 52 € for conventionally produced seed of barley varieties.

No marketing of seed of populations was reported in NL, DK and HU.

Table 2 Results of price comparison survey. Given is the percentage of the price of populations' seed compared to the seed price of regular varieties. Prices for the seed of populations were averaged over the years the seed was marketed. Prices for **organically** / **conventionally** produced seed of varieties were averaged accordingly. Comparison in Latvia was carried out to the price for **category PB** seed. Legend: ↓ less than …; ⇨ equals ….; ↑ up to 50 % more …; ↑↑ up to 150 % more …; ↑↑↑ beyond 150 % more … than average price.

MS	species / population	percentage of comparable prices		in relation to the comparable prices
DE				
	Maize			
	Evolino, Almito, Bogdan, Weihenstephaner 3	-	13	↓
		+	33	↑
	Weihenstephaner 2	-	23	↓
		+	16	↑
	Soft Wheat			
	Convento C, Convento E, Brandex, Liocharls	+	6	↑
FR	**Soft Wheat**			
	Megamix	+	21	↑
		+	84	↑↑
IT				
	Soft Wheat			
	BIO2 TENERI	+	111	↑↑
		+	193	↑↑↑
	BIOADAPT	+	104	↑↑
		+	184	↑↑↑
	MIX TENERO TOSCANA 1	-	2	↓
		+	37	↑
	MIX TENERO TOSCANA PA1	-	2	↓
		+	37	↑
	SOLIBAM TENERO FLORIDDIA	+	89	↑↑
		+	163	↑↑↑
	SOLIBAM TENERO LI ROSI	+	99	↑↑
		+	177	↑↑↑
	Durum Wheat			
	MIX DURO TOSCANA PA1	+	40	↑
	SOLIBAM DURO PETACCIATO	+	218	↑↑↑
	Barley			
	MIX48	-	16	↓
LV	**Barley**			
	Mirga	+/-	0	⇨

4.2. Populations – general aspects

4.2.1. Techniques used for generating the populations

The predominant technique for establishing the populations was technique i “crossing five or more varieties in all combinations followed by bulking of the progeny and exposing the stock to natural selection in successive generations” (73%). Technique iii “inter-crossing varieties using crossing protocols different from those in i or ii to produce a similarly diverse population that does not contain varieties” was used for 23% of the populations. Technique ii “growing together at least five varieties of a predominantly cross-fertilising species, bulking the progeny, repeatedly re-sowing and exposing the stock to natural selection until plants of the original varieties are no longer present” and a mixture of i and iii were of minor interest. (Figure 3)

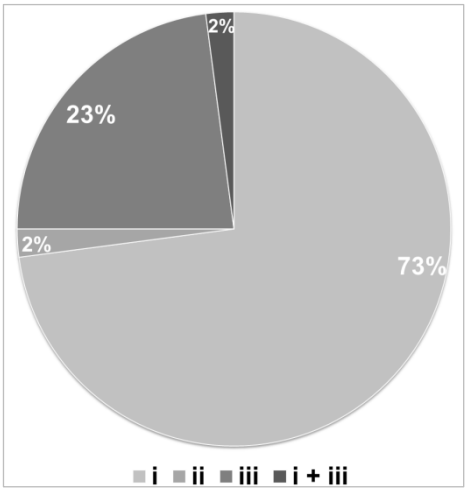

Figure 3 Percentage of technique used to develop populations.

4.2.2. Size of participating breeders and producers

Size of participating breeders and producers ranged from micro to medium. Breeding and producing companies with less than 10 employees (micro) were predominantly active. For 2020 a strong shift in size of breeding and producing companies could be observed. This shift was due to an increased demand for seed of populations in IT combined with an increased workload and thus an increased demand in personnel. The number of medium sized breeding companies decreased over time. No large breeding companies or producers were involved in the experiment. (Figure 4)

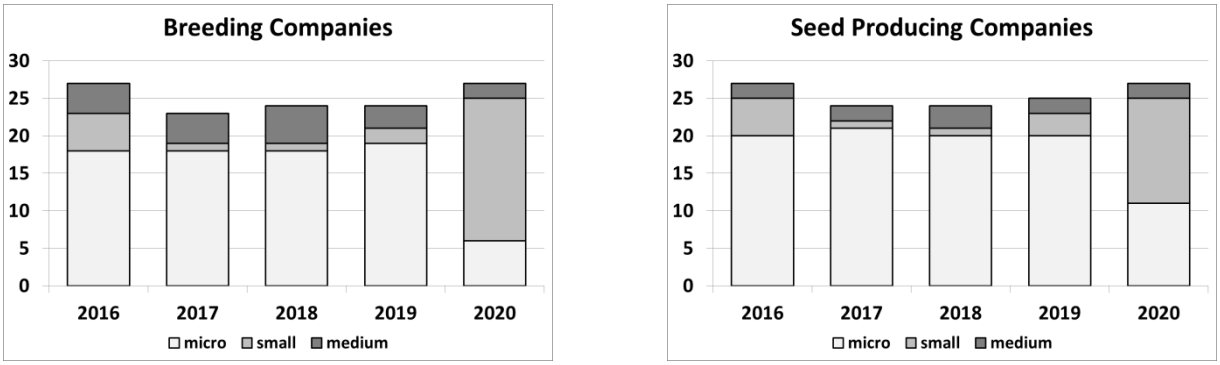

Figure 4 Size / number of breeding and seed producing companies involved in the temporary experiment. (micro: <10, small: 10 - 49; medium: 50 - 249; large: >250 employees)

4.2.3. Quantities of seed produced and marketed per population

Figure 5 and Figure 6 show the evolution of produced and marketed seed quantities over time. From 2015 to 2019 a steady increase in the produced and marketed seed quantities can be observed. An increase in the number of populations of which seed was produced and marketed is also visible. However in all years seed was produced from a higher number of populations than the number of populations which were finally marketed.

While both quantities for maize and barley stayed on a low but stable level, especially for wheat the quantities increased dramatically over time - by factor 12 from 2016 to 2017 and

factor 3 from 2018 to 2019 in case of seed production and by factor 17 and 3, respectively, for seed marketing. Information on organically produced quantities is only available for the years 2019 and 2020. In 2020 80% of the total quantity of produced population seed was organic.

Table A (Annex) displays detailed data on produced and marketed seed quantities for each population and year within the temporary experiment. Table 3 lists populations for which either an application for authorisation was filed or which were authorised but no seed was produced.

Table 3 Populations (authorised or withdrawn prior authorisation) without seed production.

Member State	Species	Breeder's reference	Technique
DE			
	Spring Wheat	Verolito A Population	i
		Verolito B Population	i
	Winter Wheat	Evolito A Population	i
		Evolito B Population	i
		Evolito C Population	i
		Evolito D Population	i
		Evolito E Population	i
		Brandex Zwei Population	i
	Barley	Diva Eins Population	n.a.
DK			
	Spring Wheat	Vårhvede-Popkorn nr 1	n.a.
		Purpur Vårhvede-Popkorn nr 1	iii
	Winter Wheat	Vinterhvede Popkorn nr 1	iii
	Spring Barley	Vårbyg-Popkorn nr 1	n.a.
		Nøgen Vårbyg-Popkorn nr 1	n.a.
	Winter Oat	Vinterhavre-Popkorn nr 1	iii
NL			
	Spring Wheat	HS ER IV-9	iii
		HS ER III-9	iii
		HSWS II 08	iii

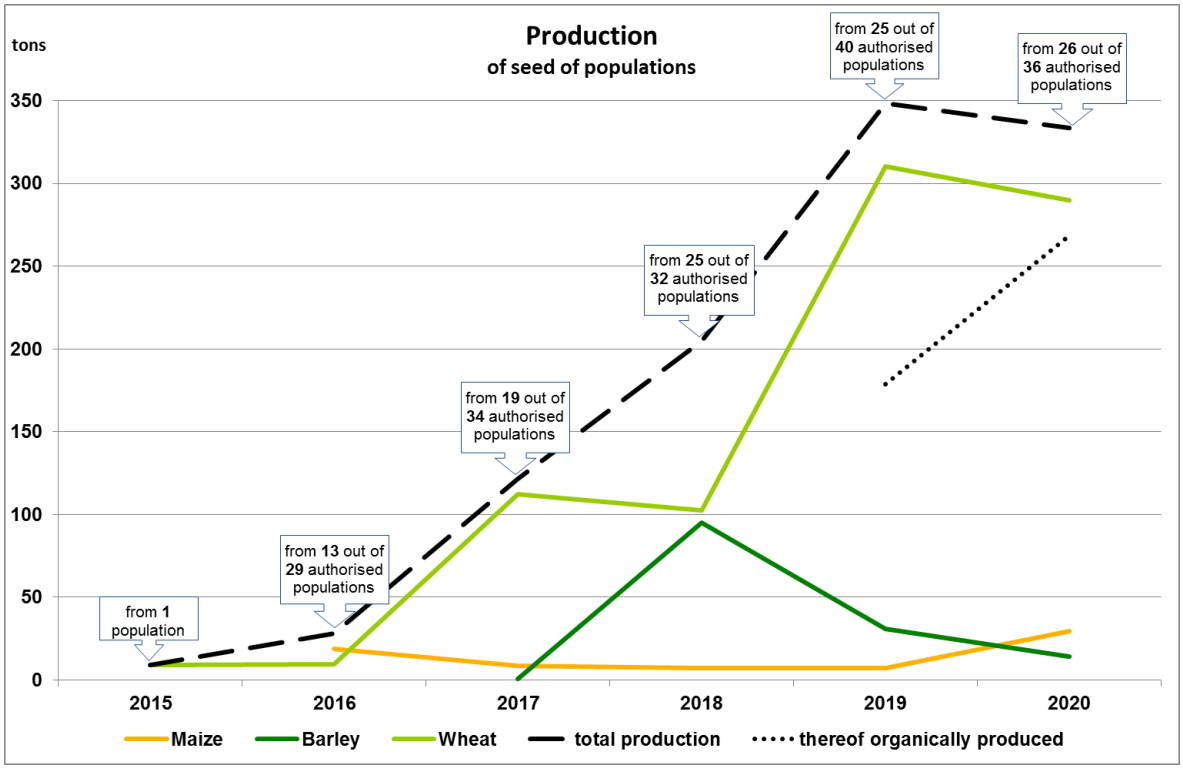

Figure 5 Amount of seed produced annually in total and species specific over all participating member states.

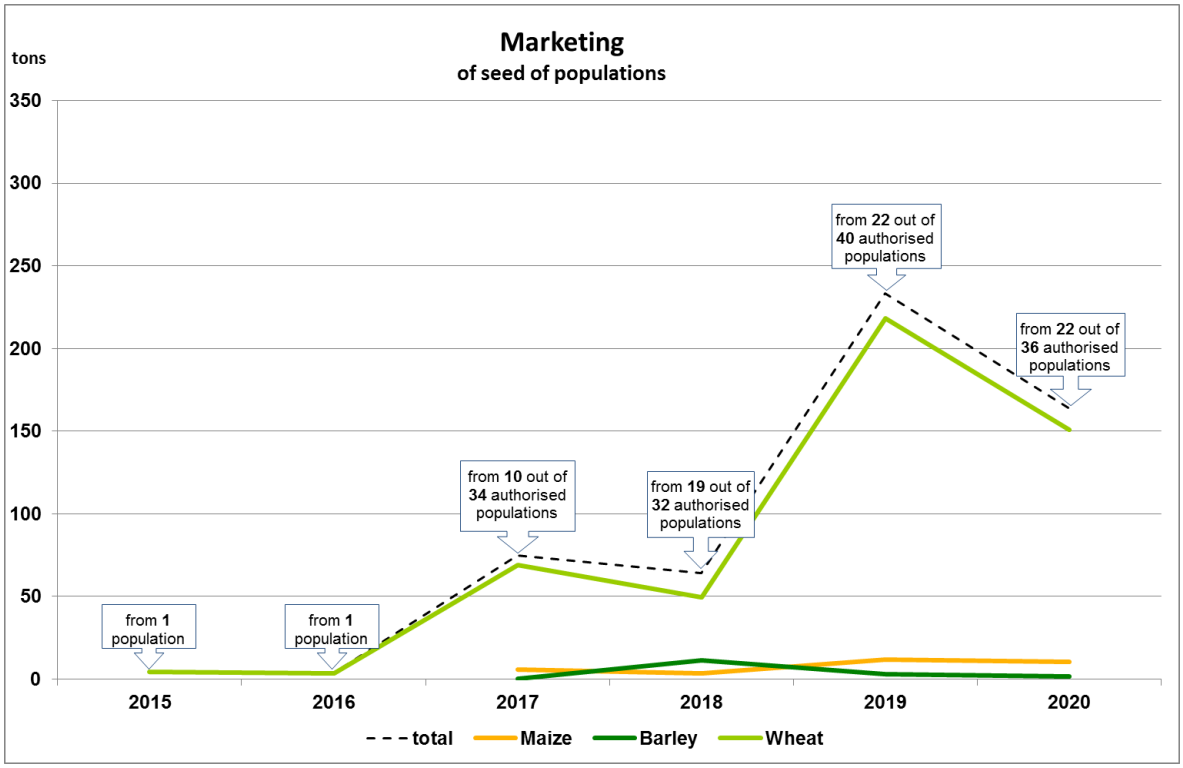

Figure 6 Amount of seed marketed annually in total and species specific over all participating member states.

4.2.4. Valuation of populations by users

In the last two to three years of the temporary experiment comments on the performance of the populations were collected from users such as farmers, millers, bakers and where possible consumers (Table 4). With only very few exceptions all users were very satisfied with the performance of the populations.

Table 4 Summary of comments from users to some of the populations.

Member State	Species	Population	User		Comments
DE	Maize	**Evolino, Almito**	**Farmers**	Production purpose:	populations intended for silage use, chicken feed - also farm saved seed production.
				Advantages:	farm saved seeds, change in the daily work routine
				Disadvantages:	slightly lower yield, inhomogeneity of the cob size resulting in an increased amount of handiwork
				Overall conclusion:	despite slightly reduced yield satisfactory overall performance, consideration to re-cultivate populations, in combination with harvestable and machine processible seed and a reasonable surcharge cultivating populations would be a "good cause".
	Wheat	**Convento C, Convento E, Brandex, Liocharls**	**Farmers**	Production purpose:	baking
				Quality:	"good for the on farm bakery" up to "high" or even "very high".
				Advantages:	improved adaptability in general and to climatic changes specifically, but also in risk spreading.
				Disadvantages:	difficulties in commercialization of grain to mills, delays in the harvest in late years, possibility to produce farm saved seed.
				Overall conclusion:	satisfiable yield, suitable for organic and also for conventional farming, consideration to further cultivate populations, interest in participation in further surveys on cultivation of populations
FR	Soft Wheat	**Megamix**	**Farmers**	Advantages:	main seed producers report good adaptation in soils with very low fertility (no lodging in low potential soils)
				Disadvantages:	population is not suitable for high potential soils due to very tall plants that lead to an increased risk for lodging
			Bakers	Quality:	baking quality (BIPEA Standards) is bad but tests for biscuits making are still ongoing
			General	Overall conclusion:	difficult to describe due to its high genetic heterogeneity (based around 100 parental lines) due to this genetic heterogeneity of interest for farmers to create their own adapted population
		TBC YQ	**Farmers**	Advantages:	population can be used under various conditions as plants are shorter and less sensitive to lodging. good compromise between yield and quality, similar to pure lines varieties used in organic agriculture in Normandy.
HU	Durum Wheat	**EPO durum**	**Farmers**	Overall conclusion:	population faced a very strong natural selection pressure due to severe drought in one location. Seeds of surviving plants were collected for propagation in 2020/21. Farmers considerate to further grow populations.
IT	Soft Wheat	**BIO2 TENERI**	General	Quality:	good flour quality therefore establishment of supply chain for production of flour, bread and other baking goods in Emilia Romagna Region.
		BIOADAPT	**Farmers**	Overall conclusion:	good productive level in relation to low impact of technical means used, good control of weed development
			General	Quality:	good flour quality therefore establishment of supply chain for production of flour, bread and other baking goods in Emilia Romagna Region.
		SOLIBAM TENERO FLORIDDIA	**Farmers**	Overall conclusion:	good productive level in relation to low impact of technical means used, good control of weed development
			General	Quality:	good flour quality therefore establishment of supply chain for production of flour, bread and other baking goods by the farm (own mill and bakery) for national market and e-commerce.
		SOLIBAM TENERO LI ROSI	**Farmers**	Advantages:	good productive level in relation to low impact of technical means used, good control of weed and disease development
			General	Quality:	flour quality well appreciated as it can characterize the short production chain with good economic return for all operators.

Table 4 (*cont.*) Summary of comments from users to some of the populations.

Member State	Species	Population	User		Comments
IT	Durum Wheat	**EVOLDUR13A**	**Farmers**	Advantages:	good productive level in relation to low impact of technical means used, good control of weed and disease development
				Disadvantages:	height of plants often causes lodging
				Quality:	due to the good quality of the flour supply chains (2019: 2; 2020: 1) for the production of pasta were created in Regions Tuscany and Marche.
		POPOLAZIONE ANGELO	**Millers**	Quality:	excellent results for quality flour observed in very small-scale milling trials
		SOLIBAM DURO FLORIDDIA	**Farmers**	Advantages:	good productive level in relation to low impact of technical means used, good control of weed development
				Quality:	good flour quality therefore establishment of supply chain for production of flour, bread and other baking goods by the farm (own mill and bakery) for national market and e-commerce.
	Barley	**MIX48**	**Farmers**	Advantages:	good productive level, good control of weed development.
				Quality:	used for zootechnical purposes
LV	Barley	**Mirga**	**Farmers**	Advantages:	Farmer 1 (seed producer), grew 'Mirga' for three seasons, is generally satisfied with appearance and yield and, interested in further use of 'Mirga' although seed distribution has been difficult so far. Farmer 2, grew 'Mirga' successfully in 2019, was surprised by its appearance in comparison with a short-stem intensive conventional variety he had in the same field. Unfortunately in 2020 'Mirga' was overgrown by the pre-crop buckwheat and only spikes of some plants could be harvested. They will form the basis for his own special population as he expressed further interest in growing populations. Farmer 3 grew 'Mirga' first in 2020 in small area but with acceptable field performance and was moderately satisfied.
				Disadvantages:	Farmer 4 grew 'Mirga' first in 2020, observed poor performance, low density of plants (possibly due to non appropiate soil conditions for barley in general) and most likely will not continue growing Mirga.
			General	Overall conclusion:	During stem elongation the population performs better than the reference variety. Possibly suitable for production of pearl barley.
UK	Soft Wheat	**Wakelyn**	General	Advantages:	Repurchase/sowing of farm-saved seed indicates that end-users are satisfied with the populations' performance.
				Disadvantages:	Possibly seed saving is limiting the sales of certified seed (no. of farmers purchasing seed has gone down but volume purchased has increased).
				Overall conclusion:	rising interest in alternative grains and genetically diverse material observed. UK Grain Lab has been formed to bring together breeders, farmers, millers and bakers to address the associated challenges and opportunities in bringing such products to market.

4.3. Populations – specific aspects

4.3.1. Field inspection and seed testing results

All Member States observed diseases and pests in the crop during field inspection. Therefore, some seed production areas did not meet the criteria for C2 standard.

LV reported infection with *Ustilago nuda* in all years with various intensities between 0 to 34 infected plants per 200m² in population 'Mirga'. The infection rate was significantly higher than the infection rate of the three control varieties. With regard to the infection rate with *Blumeria graminis* 'Mirga' was also more susceptible than most control varieties. Only for *Pyrenophora teres* 'Mirga' showed significant advantages in the infection rate compared to the control varieties.

DK informed that the oat population was susceptible to mildew and leaf spot. The winter wheat population was moderately susceptible to mildew, yellow rust (races Kranich and Warrier(-)), septoria and brown rust. One spring wheat population showed high susceptibility to mildew and yellow rust compared to control varieties, but was less susceptible to septoria. It was also susceptible to cereal cyst nematodes. Both spring wheat populations were susceptible to both races of yellow rust.

FR reported that in all years the populations showed bunt due to *Tilletia caries* and *Tilletia foetida* occurrence. However, FR described also that the amount of bunt spores could be reduced via sorting and vinegar treatment from 14,000 to 66 spores per gram of seed.

IT observed *Ustilago* in 2018 in the population 'Mix48' and in 2019, 2020 in the population 'BIOADAPT' resulting in partial rejection of the respective seed production areas.

UK reported only one infection with bunt in the population at one location in one year.

4.4. Additional data assessed

4.4.1. Extensive morphological characterisation in Italy

Following the expert working group meeting of the temporary experiment held in Magdeburg (Germany) at the beginning of July 2018, IT carried out morphological characterisation during the field inspections at the participating breeder's trial sites to assess and define methods applicable for identification of populations.

In 2019 – 2020, 12 populations (7 soft wheat, 4 durum wheat, 1 barley) were characterised by using two samples per population. Samples were based on standard material deriving from the harvest 2015 or 2017 and from breeder samples deriving from the harvest in 2016, 2017 and 2019, respectively (Table 5). Spaced plants (8 plants/m²) were sown in plots with two replications resulting in 48 plots in total.

Characterisation was carried out choosing characteristics from the CPVO protocols that were most likely able to discriminate the populations.

Data collected were analysed applying two different methods:

1. Differences for each characteristic among samples were assessed by applying the **an**alysis **o**f **va**riance (ANOVA) to all 48 samples. By comparing the means of the two samples of each population (Duncan test), differences between populations and within populations were evaluated.
2. Frequency of each note of a characteristic within a population from one year to another was assessed by Shannon's index (ecological diversity index) and diversity t-test. Comparison was carried out between both samples of a population for each characteristic.

ANOVA and Duncan test assess significant differences among analysed populations but also changes within a population from one year to another when analysing the samples belonging to the same population but collected in different years. The Shannon's index informs about the phenotype frequency composition of each population and therefore assesses the within population variation from year to year.

Consequently, ANOVA and Duncan's test can be used to assess the "distinctness" of populations and the "stability" of a population. The Shannon index can define the "identity" of a population based on its phenotype frequency.

Statistical methods reveal differences that are not visually detectable by field inspectors, but also show that obvious differences do not necessarily have to be significant.

Generally, the described methods were suitable for characterising populations as the different populations were able to be identified, also over year differences. However, they are extremely time-consuming and thus not suitable for normal field inspection. It might be feasible to use them in post-control trials depending on the total number of populations to be controlled. Here “high-definition” characteristics should be identified to enable an efficient post-control procedure.

Table 5 Overview of populations being evaluated in the Italian trials.

Species	Denomination of population	Member state	Origin of sample
Soft wheat	Evolito A	DE	Standard 2015 Breeder 2019
	Evolito B	DE	Standard 2015 Breeder 2019
	Evolito E	DE	Standard 2015 Breeder 2019
	Liocharls	DE	Standard 2015 Breeder 2019
	Bioadapt Querciola (Cà dei Fiori)	IT	Breeder 2017 Breeder 2019
	Solibam tenero Floriddia	IT	Standard 2017 Breeder 2019
	Solibam tenero Lirosi	IT	Breeder 2017 Breeder 2019
Durum wheat	EVOLDUR13 A	IT	Standard 2017 Breeder 2019
	Solibam duro Floriddia	IT	Standard 2017 Breeder 2019
	Solibam duro Recchia	IT	Breeder 2017 Breeder 2019
	Solibam duro Petacciato	IT	Breeder 2017 Breeder 2019
Barley	Mix 48 (autumn sowing)	IT	Breeder 2016 Breeder 2019

Table 6 Overview of characteristics used for analyses of populations within the different species. Legend: No significant difference detectable using this characteristic, significant difference detectable evaluating this characteristic; significant difference only in some populations detectable.

	Durum wheat	Soft Wheat	Barley
ANOVA	**Time of ear emergence** **Culm: glaucosity of neck** **Ear: glaucosity** Ear: length of awns at tip relative to length of ear **Ear: length (excluding awns)** **Plant: length** **Lower glume: hairiness of external surface** **Awn: colour**	**Time of ear emergence** **Culm: glaucosity of neck** **Ear: glaucosity** **Ear: shape in profile** **Ear: density** **Ear: length** **Plant: length** **Awns/scurs: presence** **Awns/scurs at tip of ear: length**	Flag leaf: intensity of anthocyanin coloration of auricles Time of ear emergence (1st spikelet visible on 50% of ears) Ear: glaucosity Plant: length (stem, ear and awns) **Awns: intensity of anthocyanin coloration of tips**
Duncan	Time of ear emergence Culm: glaucosity of neck Ear: glaucosity Ear: length of awns at tip relative to length of ear Ear: length (excluding awns) Plant: length Lower glume: hairiness of external surface Awn: colour	Time of ear emergence Culm: glaucosity of neck Ear: glaucosity Ear: shape in profile Ear: density Ear: length Plant: length Awns/scurs: presence Awns/scurs at tip of ear: length	Flag leaf: intensity of anthocyanin coloration of auricles Time of ear emergence (1st spikelet visible on 50% of ears) Ear: glaucosity Plant: length (stem, ear and awns) **Awns: intensity of anthocyanin coloration of tips**
Shannon + t-Test	**Time of ear emergence** **Culm: glaucosity of neck** **Ear: glaucosity** Ear: length of awns at tip relative to length of ear **Ear: length (excluding awns)** **Plant: length** Lower glume: hairiness of external surface **Awn: colour**	**Time of ear emergence** **Culm: glaucosity of neck** **Ear: glaucosity** Ear: shape in profile **Ear: density** Ear: length **Plant: length** **Awns/scurs: presence** **Awns/scurs at tip of ear: length**	Flag leaf: intensity of anthocyanin coloration of auricles Time of ear emergence (1st spikelet visible on 50% of ears) Ear: glaucosity Plant: length (stem, ear and awns) **Awns: intensity of anthocyanin coloration of tips**

4.4.2. Trials on maize and wheat populations in Germany

4.4.2.1. Trial performance of **maize** populations

Already in 2005 in DE the development of maize populations was started which finally could be marketed under the legal basis created by the temporary experiment. Comprehensive trials including nine populations and three control varieties are conducted between 2017 and 2021. Figure 7 shows that under both production systems the yield potential of the maize populations examined is between 60 to 80 % of the control varieties.

Figure 8 reveals that under conventional conditions the susceptibility to the European corn borer was for most populations higher than for the control varieties – especially when the infection pressure was higher. In years with low overall infection rate some populations performed at similar levels as the control varieties. Under organic management performance of populations was closer to the performance of the varieties. But here data were only available for two and three locations, respectively.

Infection with *Helminthosporium turcicum* (Figure 9) was rather stable on the conventional locations over the years. Infection rate in populations was always slightly elevated compared

to the control varieties. Also, at the organic trial sites with only few locations, the infection rate of the populations was mostly higher than in the control varieties.

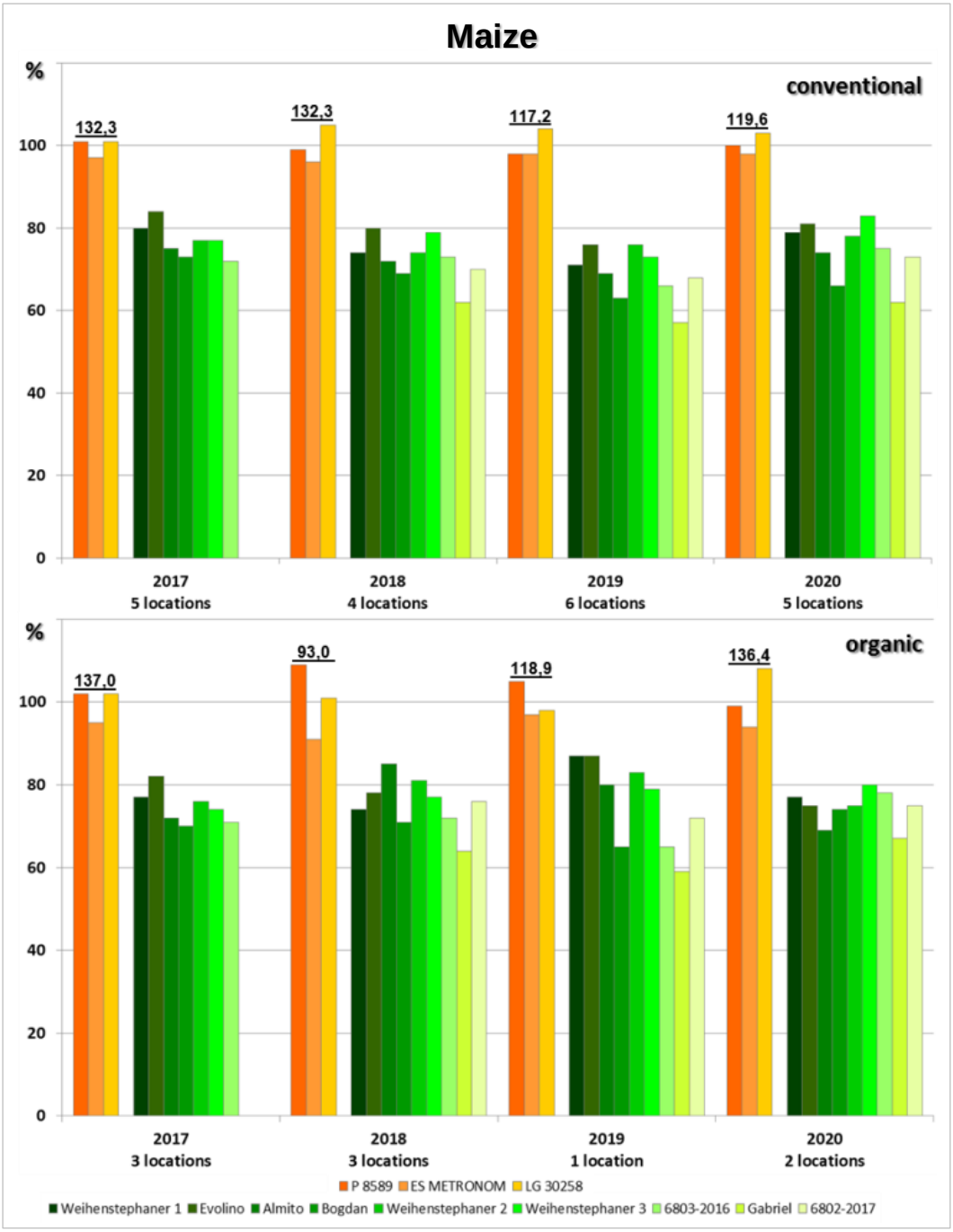

Figure 7 Relative yields of maize control varieties and populations averaged over up to six locations under conventional or organic management for years 2017 - 2020 in relation to the average yield of the control varieties (given above the control varieties in dt/ha).

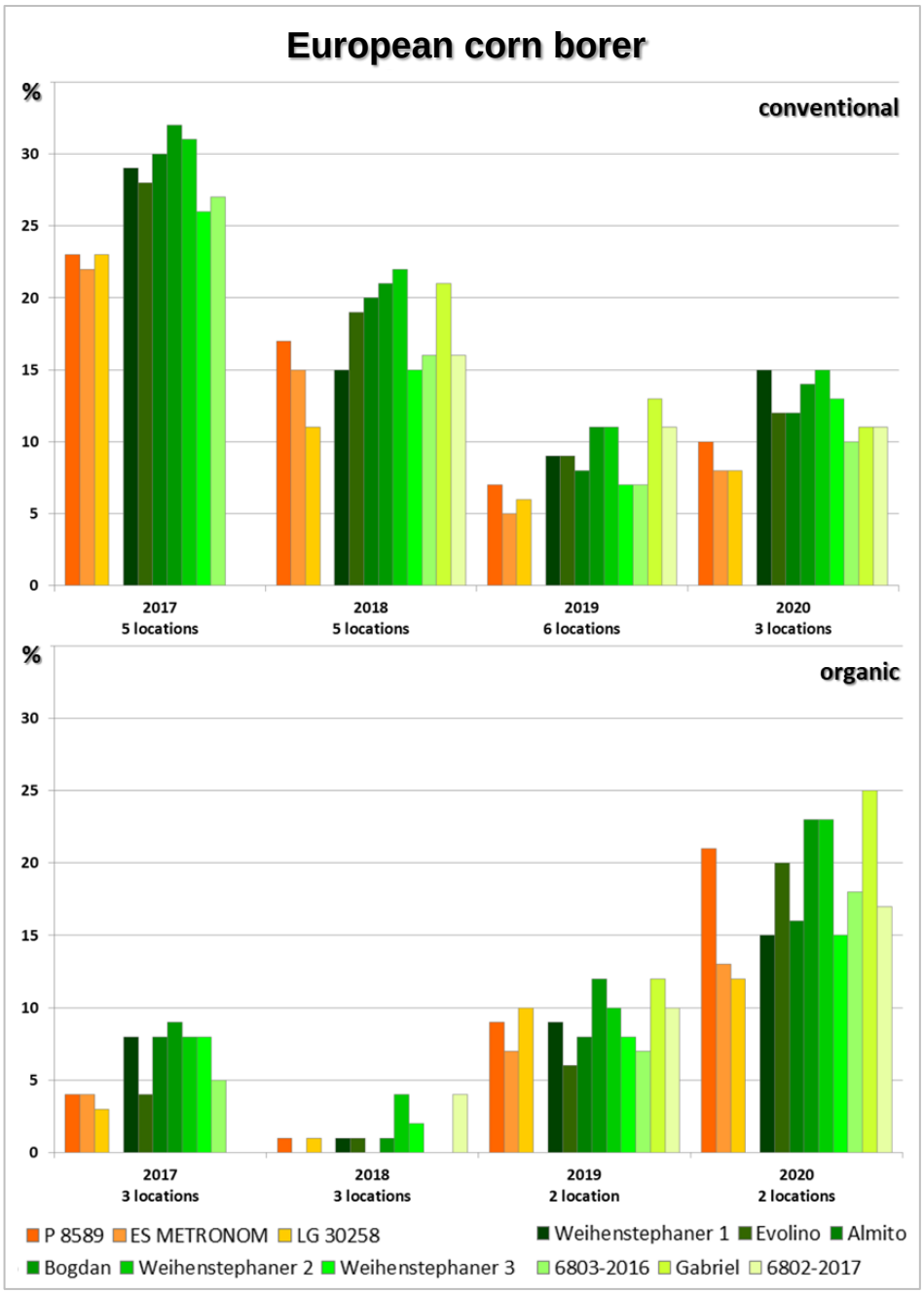

Figure 8 Mean of observed infection with European corn borer (% infected plants) at up to six locations between 2017 – 2020.

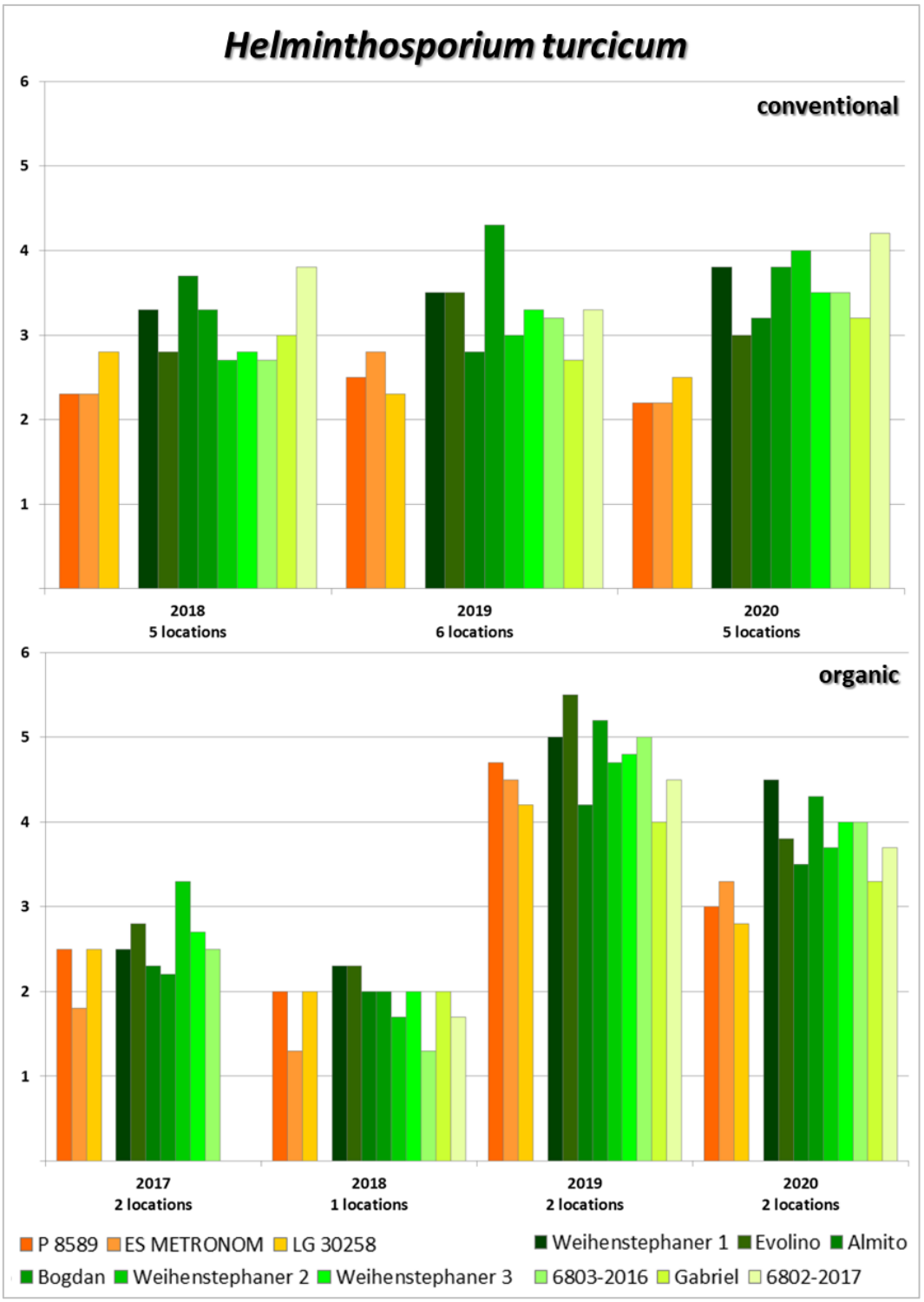

Figure 9 Mean of observed infection with *Helminthosporium turcicum* (evaluation note) at up to six locations between 2017 – 2020 (no infection of *H. turcicum* observed in 2017 under conventional management).
1: infestation absent or very low; 5: infestation medium; 9: infestation very strong

4.4.2.2. Trial performance of **wheat** populations

Figure 10 displays the yields of the seven winter and eight spring wheat populations compared to two control varieties each. Yields of winter wheat populations are comparable to the yields of the control varieties. Populations Brandex and Liocharls even outperformed the varieties in seven out of the eight trials. However,

in the German Descriptive Variety list the control varieties ´Butaro´ and ´Trebelir´ are described as low yielding.
Spring wheat populations show on conventional trial sites between 10 to 20% less yield than the control varieties. Under organic conditions a higher variation in performance between the populations is visible. Susceptibility to diseases for both winter and spring wheat was in most populations higher than in the varieties as Figure 11 and Figure 12 reveal exemplary for brown and yellow rust, respectively. However, in particular the results obtained for winter wheat for both rusts display a high variation in the susceptibility between populations.

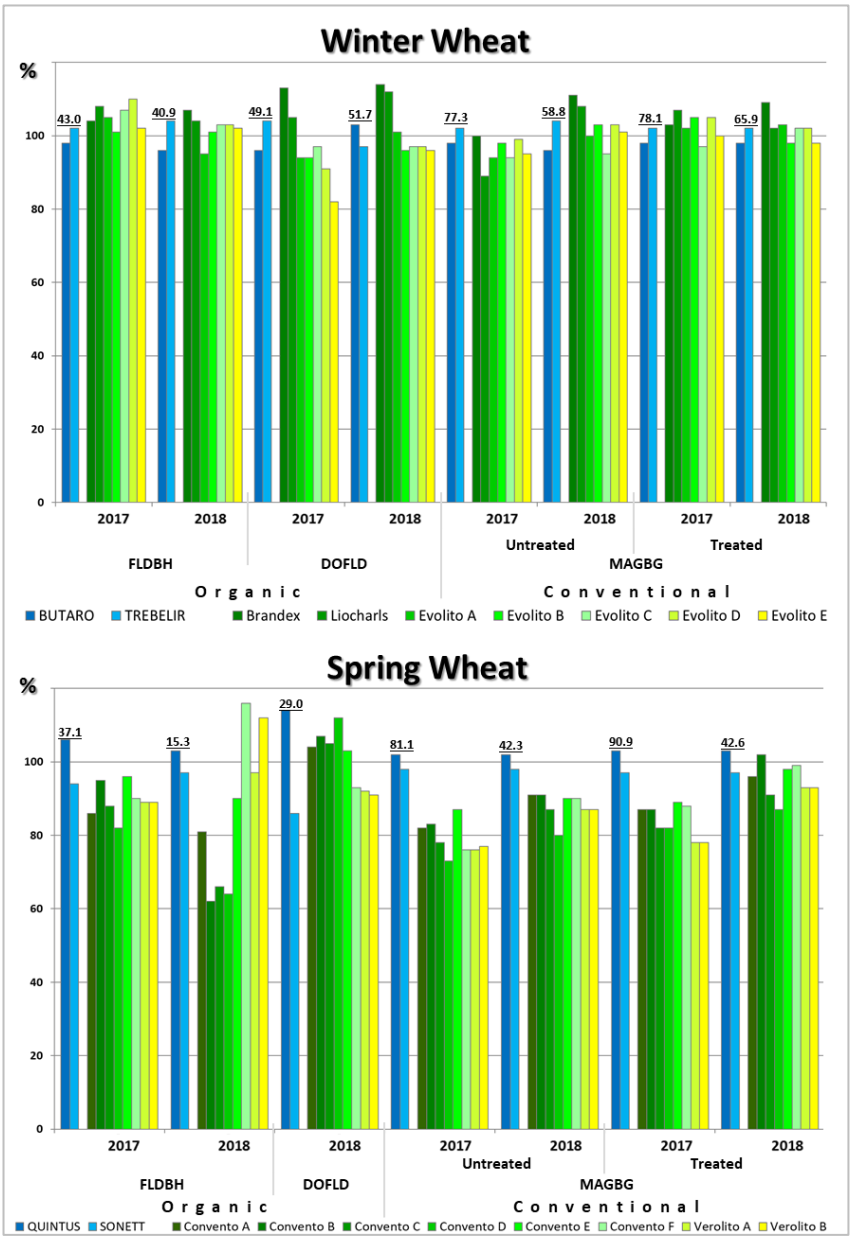

Figure 10 Relative yields of wheat control varieties (blue) and populations (green) under conventional or organic management for 2017 and 2018 at three locations (FLDBH, DOFLD, MAGBG) in relation to the average yield of the control varieties (given above the control varieties in dt/ha).
Treated: application of growth regulator and fungicides; Untreated: no growth regulator and fungicides used

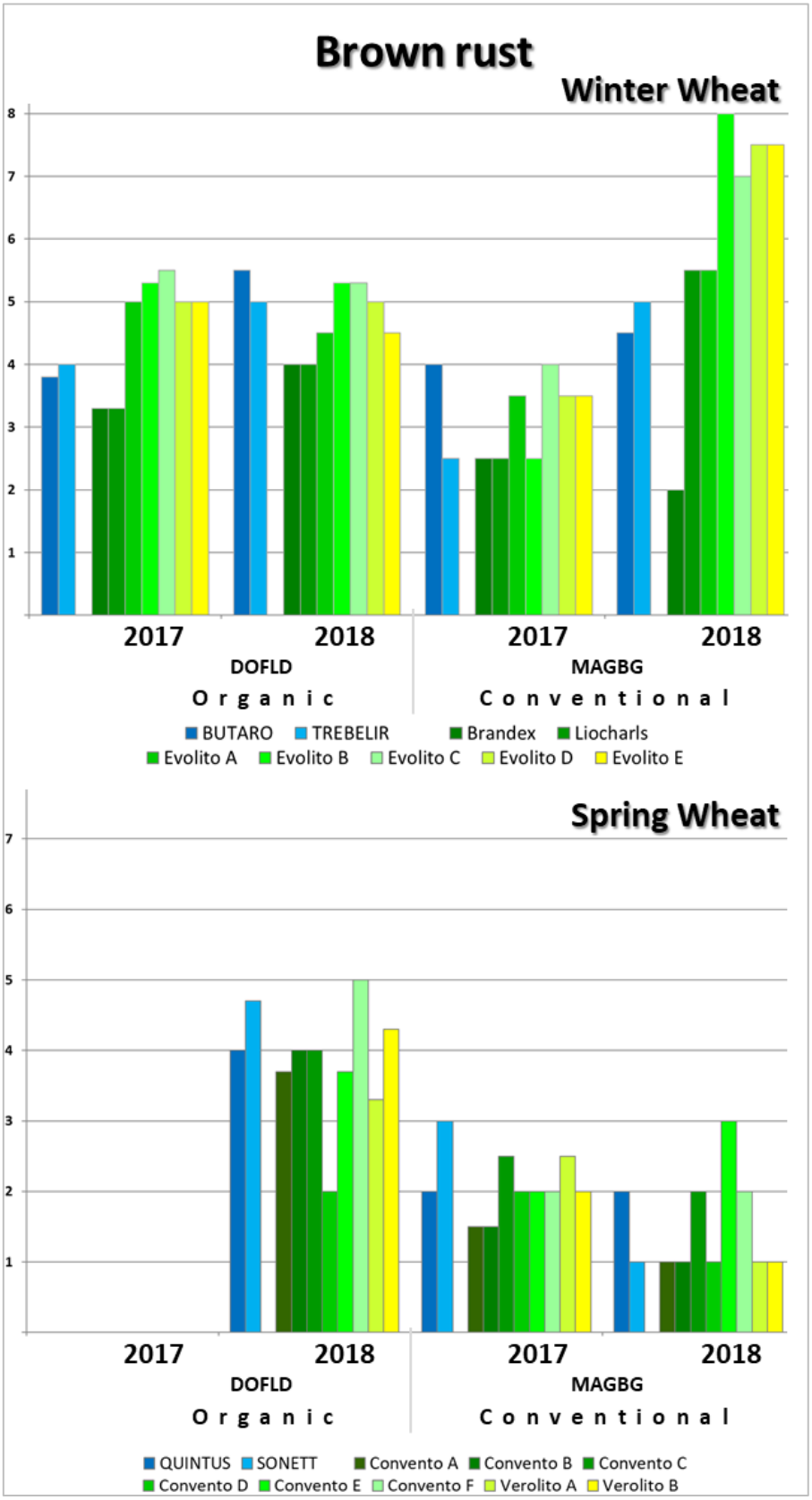

Figure 11 Susceptibility to Brown Rust at two locations (DOFLD; MAGBG) under organic (no data for Spring Wheat in 2017) and conventional management in 2017 and 2018.
1: infestation absent or very low; 5: infestation medium; 9: infestation very strong

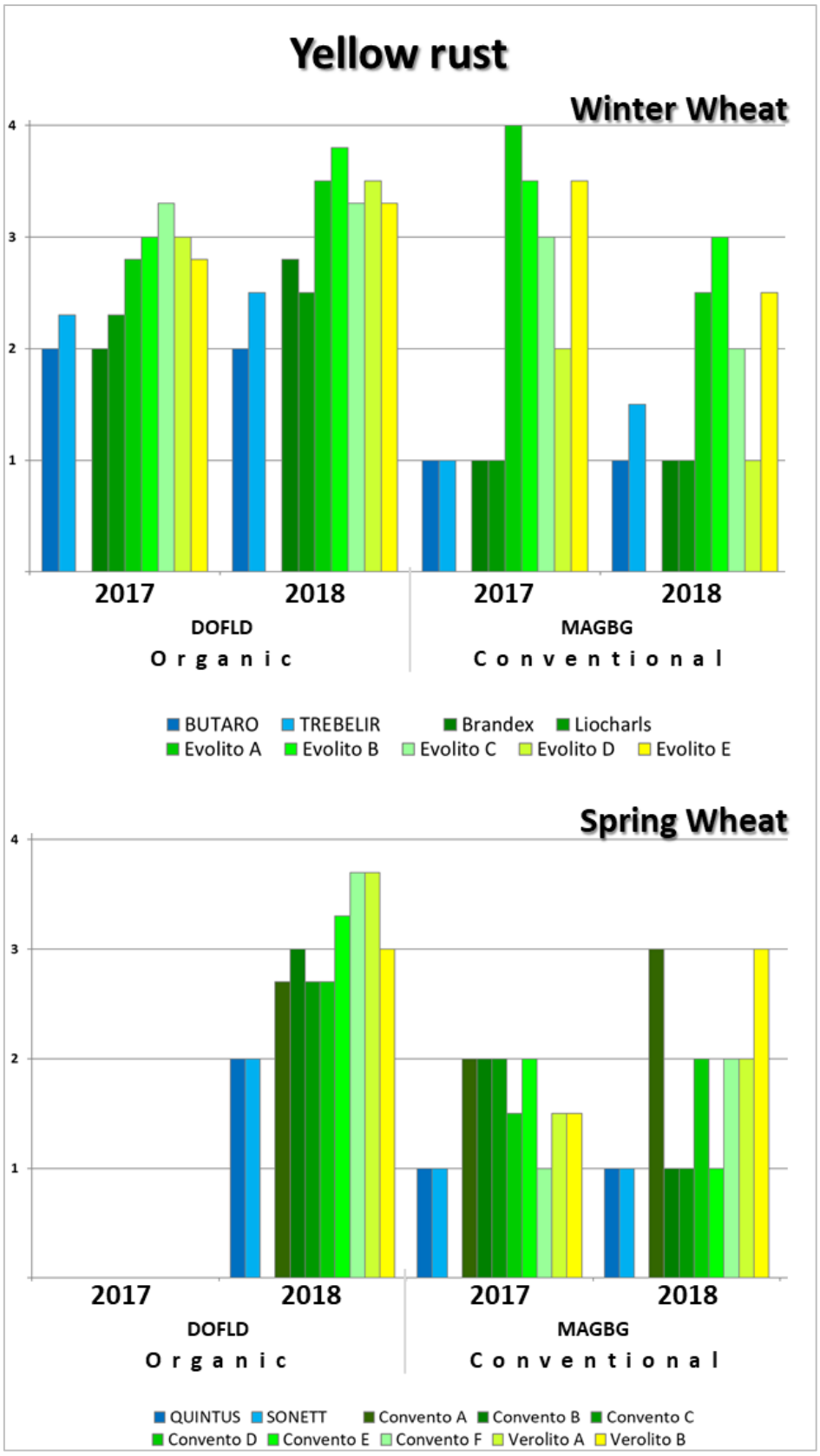

Figure 12 Susceptibility to Yellow Rust at two locations (DOFLD; MAGBG) under organic (no data for Spring Wheat in 2017) and conventional management in 2017 and 2018.
1: infestation absent or very low; 5: infestation medium; 9: infestation very strong

4.4.3. Public relations aspects/events/activities

Over the duration of the temporary experiment many activities were carried out in the participating Member States such as field days, workshops and seminars in order to promote the populations and to get into discussions with the users. Those activities were accompanied by various leaflets, videos, web pages informing about the temporary experiment, populations in general and the created populations specifically.

In the following, three projects taking place before, during and after the temporary experiment are further described.

4.4.3.1. Project around the ORC Wakelyns Population (OWP)

The UK as initiator of the temporary experiment was also the first launching and marketing a population at the beginning of 2015. The 'ORC Wakelyns Population' by the Organic Research Centre (ORC) is the result of a breeding programme using 190 crosses from 20 varieties and more than ten years of natural field selection.

Due to the high diversity within OWP alternative approaches for marketing of seed and grain needed to be found. At the beginning only one bakery used flour obtained from OWP. However, over the years various networks of bakers, millers, farmers and others were established with the intention of finding alternative ways to the grain economy of the UK for growing and processing cereals.

4.4.3.2. OpenSourceBread

In 2017, the 'Association for AgriCulture and Ecology' (AGRECOL e.V.) started a European initiative called OpenSourceSeeds in DE. Within this initiative a project called 'OpenSourceBread' (https://www.opensourceseeds.org/OpenSourceBrot) started. AGRECOL e.V., as project leader, established a network between one organic breeder, one organic farmer, one organic mill and five organic bakeries in Berlin. The aim of the project was the marketing of opensource licensed wheat. For the project the wheat population 'Convento C' was used and organically produced. The grain was processed by the organic mill which was satisfied with the flour quality. Bakeries used 'Convento C' in their flour mixtures in a range from 60 to 100% and produced bread, rolls and pastry and promoted the products specifically. In 2020 the project was extended to include also an organically producing industrial bakery. And in 2021 it is planned to further extend the network by building a new value chain for 'Convento C' in Cologne, DE.

4.4.3.3. BAKWERT

In 2020 the Bakers Association (Freie Bäcker e.V.), two departments from the University of Kassel (Department of Ecological Plant Protection, Department of Farm Management) and the Competence Centre Organic Farming Baden-Württemberg formed a network in DE (https://www.weizenvielfalt.de/). In cooperation with farmers, millers and bakers this network started a project exploring the potential of heterogeneous populations for organic production („BAKWERT" (Bewertung und Akzeptanz heterogener Weizenpopulationen in ökologischen Wertschöpfungsketten), acronym meaning 'baking quality').

The project is funded by the German Federal Ministry of Food and Agriculture. It aims at promoting the cultivation, processing and marketing of populations of cereals by using a participatory approach. Optimisation potentials along the value-added stages (cultivation, milling and baking processes) are to be developed together with the participating farms. The final results will be communicated in a "population handbook" to provide interested farmers

with a guide for the use, processing and marketing of heterogeneous populations. The project will end in May 2023.

5. Discussion

5.1. Setup of the temporary experiment

The temporary experiment started in 2014, was extended in 2018 and finished after seven years in 2021. Out of the 28 EU Member States only eight participated in the experiment. Trials and thus active participation finished early for two of the Member States. Two other Member States started their participation late and at the end of the experiment their populations were mostly still in the adaptation phase. Altogether, trials ran efficiently in only three Member States in the seven years, resulting in data on seed production for five and data on seed marketing for four years, respectively. The experimental setup of the trials varied to a great extent between the Member States due to different interests. Although seven years is the longest period an experiment of the EU Commission can run, this period must be considered as too short and the experimental set-up in the different member states as too divers to give statistically profound answers on questions on such a new approach.

The experiment allowed marketing of seed of populations of four species. Those four species account for a significant share of the cereal seed market. However, applications were only filed and seed production and marketing took only place for three species – barley, maize and wheat. Furthermore, most participating Member States focussed only on populations from one species. More than 80% of the registered populations were wheat populations. These figures combined with the number of the participating Member States indicate that the interest of marketing seed of populations is

a.) not evenly distributed throughout the 28 (now 27) Member States of the EU,
b.) not evenly distributed throughout the eight participating Member States and
c.) not equally distributed over the four cereal species.

The experiment was limited to these four species also because most research results on populations were available for them. Considering that the production area[3] of oat was only 3.6 million (m) ha in 2019 compared to wheat 26 m ha, maize 15.4 m and barley 12.3 m, it is not surprising that the interest in oat populations within the experiment is rather low. Whether a higher number of species had resulted in a higher number of participating Member States is very unlikely.

The Delegated Regulation (EU) 2021/1189 on organic heterogenic material (OHM) does not limit the species of which populations can be marketed from 1st of January 2022 on. Hence it will reveal in which Member States heterogeneous material will gain relevance on the market and furthermore for what species the concept of populations is potentially of greater interest.

5.2. Main outcome of the temporary experiment

5.2.1. Number of applications, authorisations and withdrawals

There was an obvious difference between the number of authorised and finally marketed populations. For example 40 populations were authorised in 2019 but seed of only 22

[3] https://ec.europa.eu/eurostat/web/agriculture/data/main-tables (accessed 29.11.2021)

populations was marketed. This might indicate that seed quantities produced from newly authorised populations were used for further multiplication and were not yet available for marketing, which might lead to the assumption that the duration of the experiment was too short or that it started too early as regards offer for the market. But it is also an indicator that not all populations authorised finally gained importance in the small niche markets. And even though no seed production and marketing took place such populations were not withdrawn by the applicants.

In comparison, breeders of nationally listed varieties are required to pay annual fees to keep their varieties listed. Every ten years they also need to apply for renewal. And only upon positive evaluation listing will be renewed. Both these requirements for varieties, namely fees and application for listing renewal, can be seen as control mechanisms to avoid listing of varieties without marketing activities data. As the temporary experiment was timely restricted no such control mechanisms were necessary and established. Hence, there was no need to withdraw or remove inactive populations from the list leading possibly also to a difference in the number of authorised vs. marketed populations.

Applications were withdrawn either due to high susceptibility against pests and diseases (NL, DK), low yield (DK) or due to low demand (DE).

5.2.2. Development of seed market prices

There were great differences between the participating Member States in regard to the prices charged for seed of populations (Table 2; raw data Table II, Annex). Compared to prices for seed of varieties, prices in DE were either slightly elevated (conventional) or slightly depressed (organic), in FR prices were slightly elevated but in IT a drastic increase in price could be observed. IT had listed mainly wheat populations and many supply chains were created around the populations. Also, a general increase in the demand for regionally and organically produced food was reported, further pushed by the pandemic, which might have supported the observed price development. DE reported build-up of supply chains for wheat populations. Here specifically due to the pandemic an increase in the general interest for organically or regionally produced goods was observed. However, in DE prices of populations of all species were kept quite stable compared to varieties and was not influenced by the demand. Therefore, it is not really foreseeable how the prices will develop in the future under the new regulation for organic heterogeneous material. Whether higher seed prices will compensate for lower yield and higher susceptibility remains to be seen. Furthermore, prices of the final produce would also need to be higher to compensate for lower yields.

5.2.3. Quantities of seed produced and marketed per population

More than 80% of the authorised populations were wheat populations. Therefore not surprisingly the biggest seed quantities produced and marketed were also from wheat populations. Two increases in produced and marketed seed quantities could be observed. The first increase by factor 12 and 17, respectively, might be due to the increase in number of populations that were multiplied; the second increase by factor 3 might be due to an increase in the demand for seed of populations. The observable decrease in both quantities in 2020 is most likely due to the finalisation of the experiment in 2021 and thereof resulting marketing restrictions for the seed of populations.

However, not visible in the collected data is the amount of farm saved seed that was used. Populations are supposed to adapt to certain agro-climatic conditions. This adaptation

process is further enhanced by the use of farm-saved seed. Some seed distributors and also farmers stated that farm saved seed was produced; indicating that although this seed never entered the market the relevance of populations might be greater than the collected data suggest.

5.3. Authorisation procedures

In all Member States the authorisation process was constructed simple and with minor bureaucratic burdens.

5.4. Identification and traceability of seed of populations

Populations present a great challenge in terms of identification and traceability as they cannot be identified by the general means used for varieties (phenotypic and additionally genotypic evaluation). As per definition populations are genetically and thus also phenotypically highly diverse and determining characteristics with stable unique expressions over several propagation cycles is highly unlikely. IT conducted in depth analyses to find answers to whether and how populations can be identified and traced by phenotypical and statistical means.

A very labour intensive trial was conducted using up to nine morphological characteristics and analysing them over three years. This study came to several conclusions:

a) populations can be characterised and identified using morphological characteristics and statistical analyses,
b) using statistical methods in populations is extremely time-consuming and labour intensive and hence not applicable to normal field inspection,
c) statistical methods for identification and characterisation of populations might be applicable in post control procedures,
d) obvious differences in the field might not necessarily be significant and therefore the evaluation of morphological traits should always be supported by statistical analysis.

During the temporary experiment a discussion arose on how helpful the use of biomolecular technologies might be. Research showed that phenotypic and genotypic identification of populations and a description of the degree of heterogeneity can be achieved using molecular techniques. However, these methods are far too time consuming for regular field inspection and post control.

Between the participating Member States it was finally agreed that the most adequate method of identification was traceability via documentation. Already during the authorisation process information was requested and populations were characterised by the breeding and production methods used. IT reported good experience by adding to the original name of a population the name of the region it was further developed in.

5.5. Yield, quality, disease and pest resistance of populations

Trials conducted in the UK prior to the start of the temporary experiment showed populations to be more resilient than single varieties and having a greater capacity to buffer against adverse environmental conditions and diseases. They also showed to have a higher yield than the mean of their parent varieties and to have a more consistent performance from year to year.

Trials conducted in DE were based on VCU guidelines with some additional characteristics. In case of maize yield was between 60 – 80% compared to the yield of the control hybrid varieties. For wheat the difference was only 20% and in some years some populations could even outyield the control varieties. Baking quality was good to even very good. These results were achieved under organic and conventional conditions. For all trials the focus lied on the performance of each population and was not aimed at a general comparison to varieties. The number of varieties included was limited, as their purpose was only to provide a reference.

The results from DE do not generally confirm a higher resilience and a greater capacity to buffer against adverse environmental conditions and diseases as revealed by the UK trials. In fact the trials conducted in DE, but also results from other Member States implicate that susceptibility against pests and diseases was for some populations higher than for the control varieties. Multiplication areas sometimes had to be excluded to assure seed quality will meet C2 standard. Hence, inspections and phytosanitary measurements are of great importance when working with populations and special attention should be paid to organic heterogeneous material in this regard.

Altogether, results of the UK research, that populations are generally more efficient in compensating challenging environmental conditions, cannot be confirmed. It is highly depending on the specific population used and its genetic background. Hence, only population-specific statements can be given. Especially the German results on populations highlight differences in yield performance and resistances, probably based on the genetically different varieties used as source material. However, the observed differences between populations indicate that there might be potential for higher yielding and more resilient populations in the future.

5.6. Valuation of populations by users

Results from IT, DE and UK vividly display that the concept of populations works best when local or regional networks consisting of farmers, millers, bakers and scientists are created and regional or niche supply chains are built around them. Also breeding and seed producing companies involved were mainly of micro to small size. Farmers testing populations were open minded, curious and interested to support “a good cause”. Even though also trials under conventional conditions were undertaken generally populations are destined for organic production or production in marginal areas. It is therefore not foreseeable that populations will replace individual varieties or variety mixtures in the near future.

6. Conclusion

- The main conclusion of the temporary experiment is that the identification of populations cannot be ascertained in the context of regular field inspection and post control. The experiment revealed that populations can be identified using statistical methods and methods based on the application of molecular markers. However, these are too costly and time consuming to complement or replace regular field inspection and post control. Furthermore, the adaption of populations to local conditions results in the loss of their initial identity. Therefore, field inspection can only focus on health status, general crop appearance, contamination with other species and, if necessary, minimum distance to other crops.

- To ensure the identity of the seed of populations, traceability requirements must be specified and a control system must be in place.
- Results of the comparative field trials within the temporary experiment revealed that only population specific conclusions in regard to yield, quality and disease and pest resistance should be drawn as the populations differ in these aspects.
- Based on the example of wheat it can be concluded that the concept of populations works best when simultaneously networks and supply chains were developed.

7. Annex

Table A Registered populations with seed production and marketing of seeds.

Member State	species	population	TQ	produced in kg							thereof organically produced in kg			marketed in kg						
				2015	2016	2017	2018	2019	2020	total per population	2019	2020	total per population	2015	2016	2017	2018	2019	2020	total per population
DE	Maize	**Evolino**	**i**		5,000	5,000	5,000	5,000	6,000	**26,000**	5,000	6,000	**11,000**			1,616	2,656	4,845	5,148	**14,265**
		Almito	**i**		2,000	500	650	650	500	**4,300**	650	500	**1,150**				25	620		**645**
		Bogdan	**i**		2,000	1,000	100	100	100	**3,300**	100	100	**200**			114	560	80		**754**
		Weihenstephaner 2	**iii**		9,635				21,505	**31,140**		21,505	**21,505**			4,200		5,445	4,290	**13,935**
		Weihenstephaner 3	**iii**			2,000	1,500	1,500	1,500	**6,500**	1,500	1,500	**3,000**				256	1,024	1,284	**2,564**
	Spring Wheat	**Convento A**	**i**		50	400				**450**							60			**60**
		Convento B	**i**		50	400				**450**							60			**60**
		Convento C	**i**		50	400	1,500		5,000	**6,950**		5,000	**5,000**				300		2,000	**2,300**
		Convento D	**i**		50	400				**450**							60			**60**
		Convento E	**i**		50	400	2,000	6,000	3,000	**11,450**	6,000	3,000	**9,000**				350	650		**1,000**
		Convento F	**i**		50	400				**450**							50			**50**
	Winter Wheat	**Brandex**	**iii**		100	800	4,000	14,000	61,000	**79,900**	14,000	61,000	**39,000**			19	450	6,100	14,257	**20,826**
		Liocharls	**iii**		100	800	2,000	4,000	54,000	**60,900**	4,000	54,000	**12,000**			7	450	2,890	6,595	**9,942**
FR	Soft Wheat	**Megamix**	**i+iii**					11,530	1,000	**12,530**								200	25	**225**
		TBC YQ	**i**					12,860		**12,860**								200		**200**
HU	Durum Wheat	**EPO durum**	**iii**						120	**120**										
IT	Soft Wheat	**BIO2 TENERI**	**i**					2,520	3,800	**6,320**	2,520	1,395	**3,915**					1,536	1,395	**2,931**
		BIOADAPT	**i**			50,600	17,750	22,775	14,968	**106,093**	22,775	14,968	**37,743**			45,387	14,275	20,000	14,968	**94,630**
		APPENBIO	**i**						379	**379**									379	**379**
		CAROSELLA LUCANA	**i**					3,000	10,000	**13,000**								1,700	8,000	**9,700**
		MIX TENERO TOSCANA 1	**i**					1,560	25,237	**26,797**	830	6,990	**7,820**					1,560	25,237	**26,797**
		MIX TENERO TOSCANA PA1	**i**					23,400	26,700	**50,100**		26,700	**26,700**					14,006	26,700	**40,706**
		PEOPLE	**i**						3,600	**3,600**									3,600	**3,600**
		SOLIBAM TENERO FLORIDDIA	**i**			4,200	4,700	22,400	18,700	**50,000**	22,400	18,700	**41,100**			1,875	2,400	6,000	18,700	**28,975**
		SOLIBAM TENERO LI ROSI	**i**			17,000	23,500	31,200	17,100	**88,800**	31,200	17,100	**48,300**			14,000	20,000	31,200	17,100	**82,300**
	Durum Wheat	**EVOLDUR13A**	**i**				33,700	22,770	24,625	**81,095**	12,450	9,728	**22,178**				1,479	4,792	8,728	**14,999**
		MIX DURO TOSCANA PA1	**i**					6,300	5,500	**11,800**	3,500	2,624	**6,124**					2,345	2,624	**4,969**
		POPOLAZIONE ANGELO	**i**					285		**285**	285		**285**							
		SOLIBAM DURO FLORIDDIA	**i**			3	100	300		**403**	300		**300**							
		SOLIBAM DURO PETACCIATO	**i**				20	250	15,000	**15,270**		15,000	**15,000**						375	**375**
		SOLIBAM DURO RECCHIA	**i**			5		42	200	**247**									200	**200**
	Barley	**MIX48**	**i**			642	92,400	12,500	11,700	**117,242**						100	11,000	2,750	1,300	**15,150**
LV	Barley	**Mirga**	**i**				2,700	18,400	2,400	**23,500**	18,400	2,400	**20,800**				250	300	590	**1,140**
UK	Soft Wheat	**Wakelyn**	**ii**	8,880	8,900	36,500	13,360	125,000		**192,640**	35,000		**35,000**	4,500	3,750	7,750	9,500	125,000		**150,500**
total per year / overall				**8,880**	**28,035**	**121,450**	**204,980**	**348,342**	**333,634**	**1,045,321**	**178,910**	**268,210**	**367,120**	**4,500**	**3,750**	**75,068**	**64,181**	**233,243**	**163,495**	**544,237**