Report on the Analysis of the bottlenecks and challenges identified for on-farm maintenance and breeding in European agricultural conditions

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Report on the Analysis of the bottlenecks and challenges identified for on-farm maintenance and breeding in European agricultural conditions

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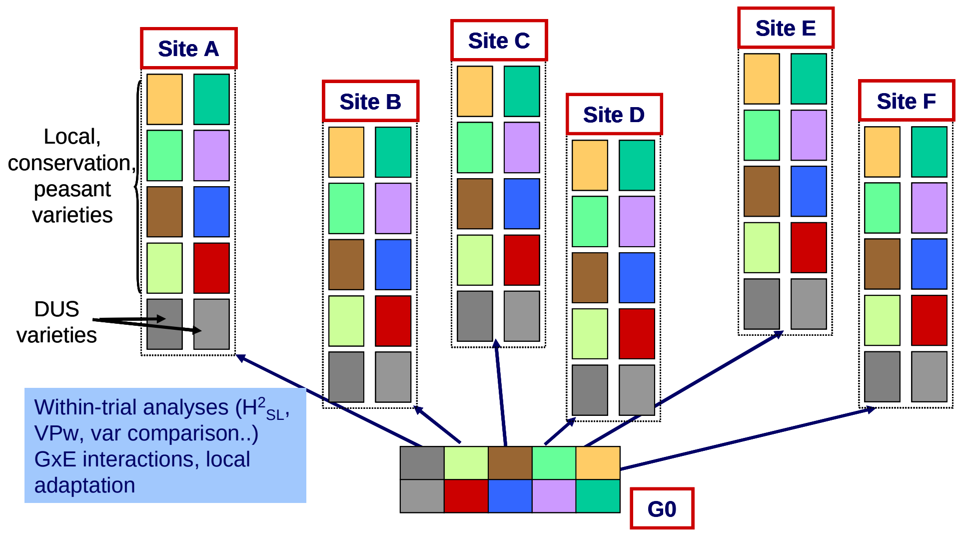
1 Objectives and description of the experiments

1.1 – Objectives and design of the experiments

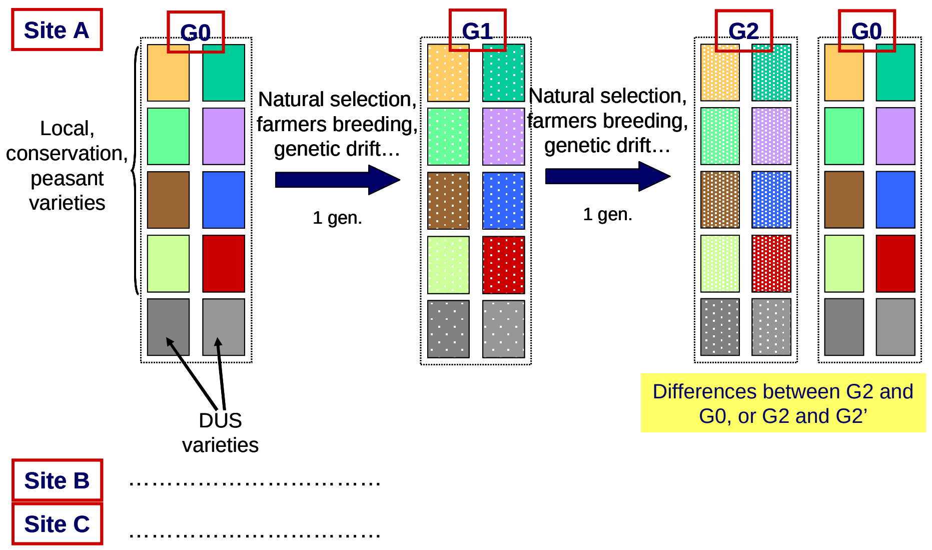
In the FSO project, on-farm field experiments were conducted with “non-conventional varieties” (landraces, old varieties and new farmers varieties) during the 3 consecutive years of the project (2007-2009) with the objectives of assessing the evolution / adaptation over time and space of these varieties when they are moved from one environment to another. The varieties were characterized for their average behaviour and their variability for different traits, within and among environments. These experiments were carried out in The Netherlands, Italy and France under the responsibility of the following partners: INRA, RSP, LBI, DLO, IGSA and AIAB. IIED provided advice and helped design participatory methodologies.

A large experiment of 25 trials on 4 species (wheat, maize, bean and spinach) started in 2007 (or autumn 2006 for bread wheat) and was conducted for three years in the three countries according to the experimental designs given below. In 2009, in addition to the on-farm evaluation of the third generation of each variety cultivated on-farm, a common-garden experiment was conducted in one site (Le Rheu experimental station) under organic management. This allowed us to compare samples of the varieties grown for two generations in all farms in France, in the Netherlands and in Italy with the initial or reference samples for the same varieties.

First season general design (2007):



General process over the three years:



1.2 – Specific features of each species experiment:

Each species underlines a specific aspect of plant breeding / on-farm conservation. For maize and spinach, mass selection was applied by the farmers which allowed us to characterise the effect of the farmers' selection and practices. For beans, various breeding strategies have been developed by the farmers illustrating the diversity in the ways farmers interact with the varieties (see the table below). For wheat, very little or no selection was applied by the farmers so the experiments mostly assessed the effects of natural selection/adaptation within each environment.

	RG	BV	Arsiero	Feltre	CV	JM	BG	JLB	JJM
Culinary tests	-	On some varieties	-	-	X	-	-	-	-
Selection of variants	In some varieties	In some varieties	In one variety (SR)	-	-	X (but no time to sow them)	In one variety	In all the varieties	-
Selection on productive aspects	X	-	-	-	-	-	-	-	-
Selection on physiological criteria	Within Suisse Rouge: not climbing	-	-	-	-	-	Within Suisse Rouge: not climbing	-	-
Selecting varieties for purity	For a part of the seeds (to maintain the original population)	For most of the varieties	X	X	X	X	For Flageolet Chevrier	-	-
No selection	-	-	-	-	-	-	For Suisse Rouge	-	For all varieties
Elimination of some varieties	X	X	-	-	-	-	-	X	X
Selection of healthy seeds (without viruses)	X	X	-	-	-	-	-	-	

1.3 – Main conclusions from the experiment over three years:

The FSO on-farm experiments and at le Rheu, based on four crop species, allowed us to obtain an accurate characterization of variety evolution over time and space in response to drastic environmental changes and contrasted farmers' practices on-farm. Overall, after only 2-3 years of on-farm growing and selection, there were significant changes for many traits assessed both on-farm and on-station. The significance and degree of evolution depended on the trait studied, the varieties, the farmers' practices and farm environmental conditions. Although there were fewer traits showing significant changes this trend of on-farm evolution was also found for modern DUS varieties. Yet, all varieties remained distinct based on multivariate assessment.

2 Identification of the bottlenecks and challenges for the on farm maintenance and breeding in European agricultural conditions in relation to seed regulation

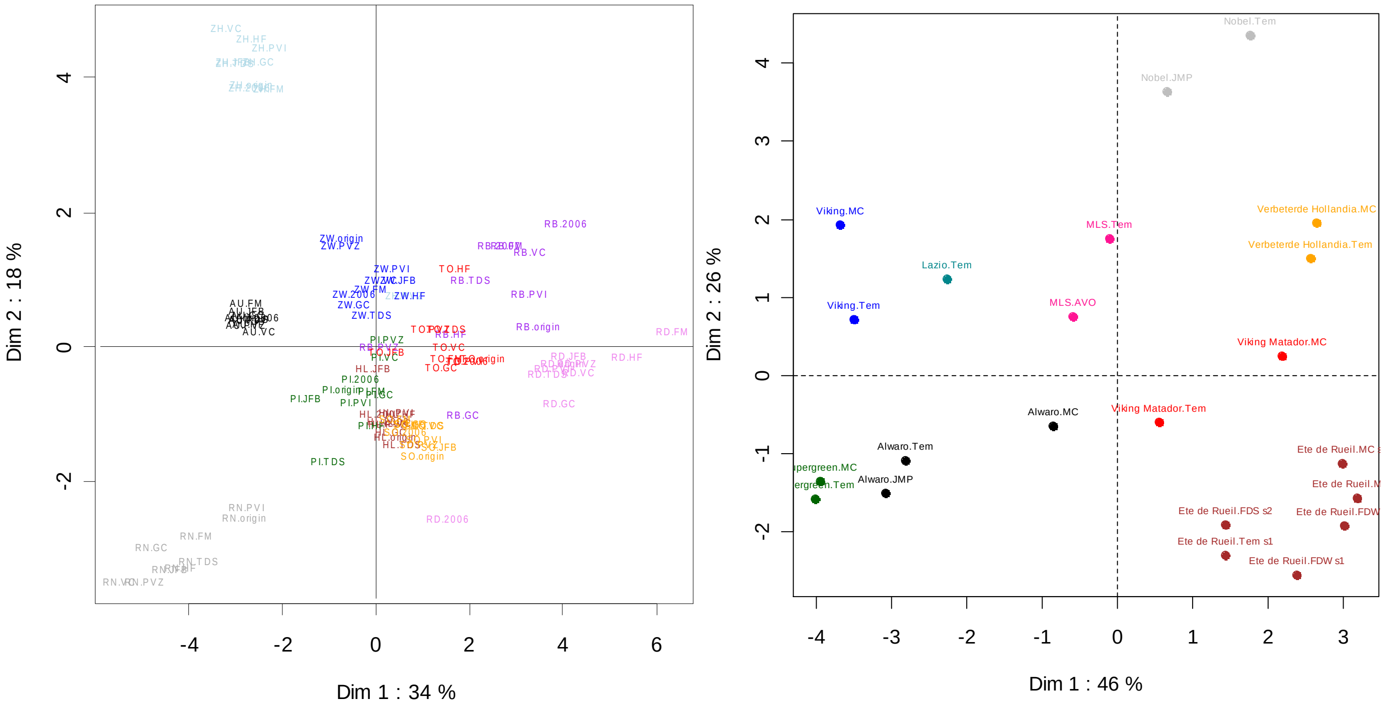
2.1 Distinctiveness among varieties

Distinction among varieties using phenotypic observations (in the field or on harvested grains/material) was always possible: on-farm experiments and the common experiment at Le Rheu always had a significant main effect of the variety in ANOVA for each measured character. This was true even in the presence of strong GxE interactions which modified phenotypes from one farm to another and even when varieties appeared heterogeneous

The landraces were more diversified than the varieties registered in the official catalogue. A multivariate analysis (PCA) based on the common wheat experiment at le Rheu showed that while the versions of each variety diverged, they always grouped in separate varietal clusters (see Figure 1A). This was also true for spinach (see Figure 1B).

2.2 Homogeneity of varieties

The UPOV protocols define homogeneity as a percentage of "off-type" plants; this seems difficult to apply in the case of landraces, population or new farmers' varieties. In the FSO experiment, measures on individual plants for each variety and in each trial were used to assess the level of homogeneity within each variety. For a few criteria (e.g. plant height for wheat, Figure 2), the varieties registered (official catalogue) were more homogeneous than the landraces. However, for the majority of phenotypic traits measured, under on-farm conditions the level of intra-varietal heterogeneity was comparable among landraces and modern varieties (e.g. Grain weight per spike, Figure 2).



A **B**

Figure 1. **A-** Principal component analysis of the different versions of the 10 **Wheat** varieties evaluated in the Le Rheu 2009 trial (based on 18 quantitative traits measured on plants, spikes and grains). **B-** Principal component analysis of the different versions of the 9 **Spinach** varieties (including the hybrid variety Lazio) evaluated in the Le Rheu 2009 trial (based on 7 qualitative and 6 quantitative traits)

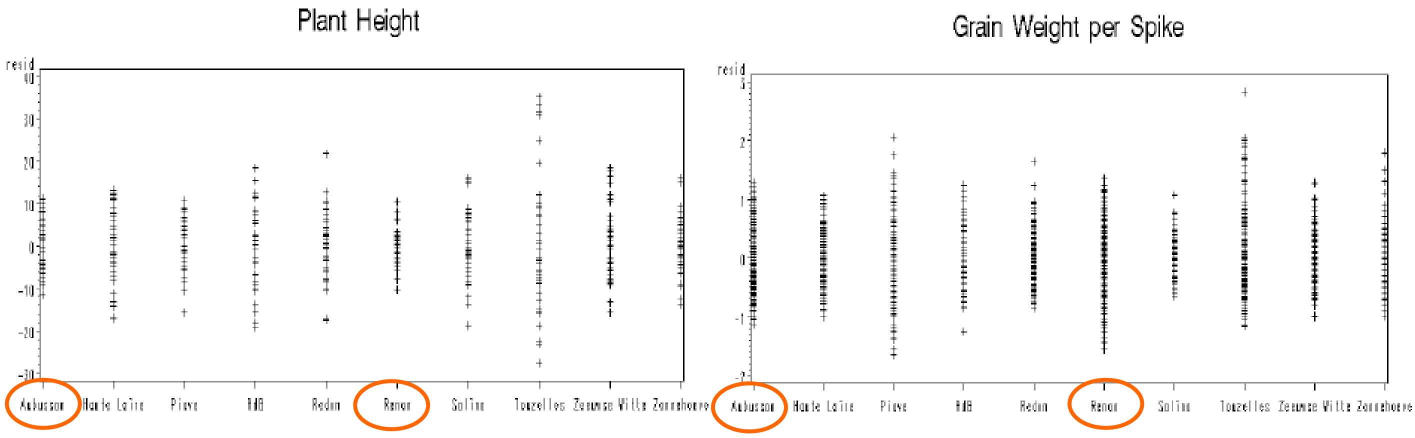


Figure 2. On-farm experiment in 2007. Standardized residuals of each variety from the ANOVA analysis including GE interactions as a measure of intra-varietal phenotypic variation. The two modern registered varieties (Aubusson and Renan) are circled in orange.

Thus, based on the FSO experimental results, the standard of homogeneity as understood in UPOV and the official catalog is not relevant and does not make sense when varieties are observed and described on-farm under organic or low-input conditions. True "off-type" plants that occasionally appeared in a variety (e.g. in beans) were not always identified as problematic by farmers, and in fact could be plants of great interest for certain farmers (Figure 3).

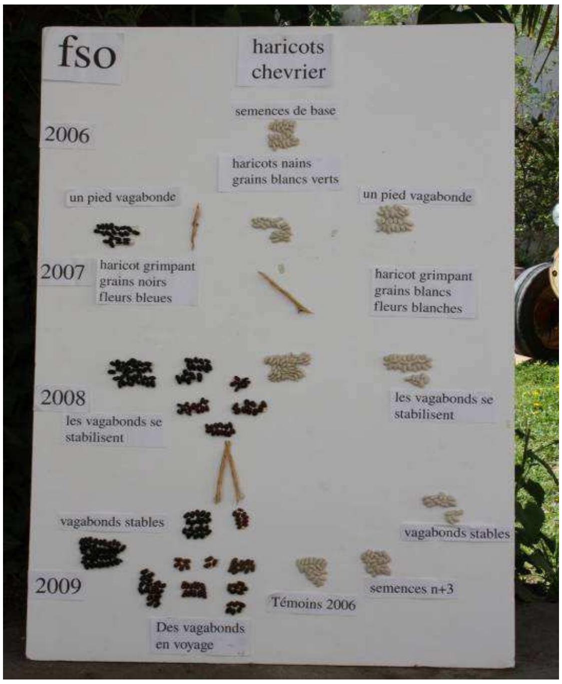


Figure 3: Genealogy of different progenies of Flageolet Chevrier variants that have been selected by JLB, photo of seeds issued from 3 cycles of multiplication and selection. JLB studied the progeny of the different off-types in order to develop new types or varieties.

2.3 Stability

Stability in space: A single initial variety, cultivated in contrasting environments (the Netherlands – France - Italy) could (i) perform differently depending on the environment (GxE interactions), (ii) evolve in a different manner in each environment depending on environmental and cultural conditions in the course of only two years of differentiation. Landraces were neither more nor less “stable” than modern varieties over the 6 farms in terms of GxE crossover interactions (Figure 4).

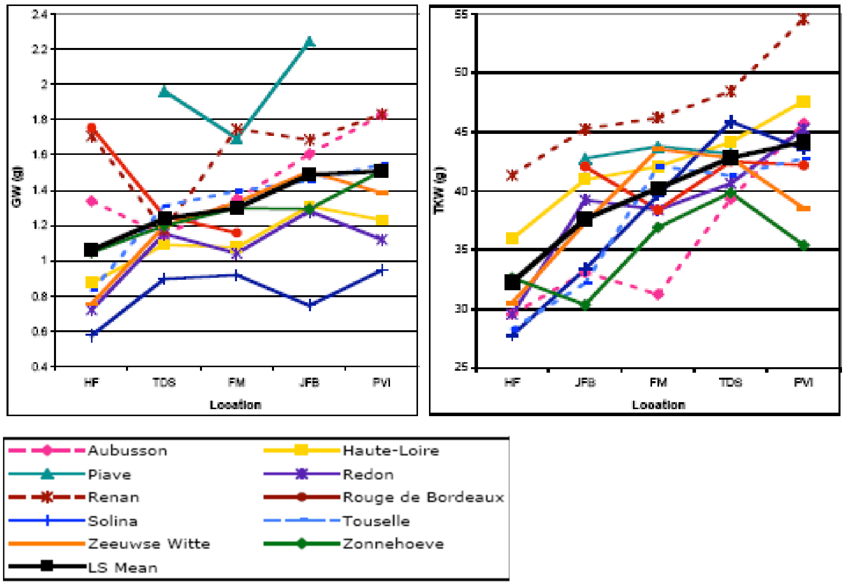


Figure 4: Least Square Mean value for Grain weight (GW) and Thousand kernel weight (TKW) in each location and of individual variety means for each trait and each location in 2007 on-farm wheat experiment.

The case of the variety Coco du Cheylard illustrates how some traits (here seed and pod shape and color in Figure 5, but also leaf shape and colour) may vary from one environment to another but did not produce off-types. However, this variety, which is a traditional variety from Ardèche (France) has some common characteristics: it is resistant to mildew and thus it can be cultivated in any season, and it also has a very early flowering time.

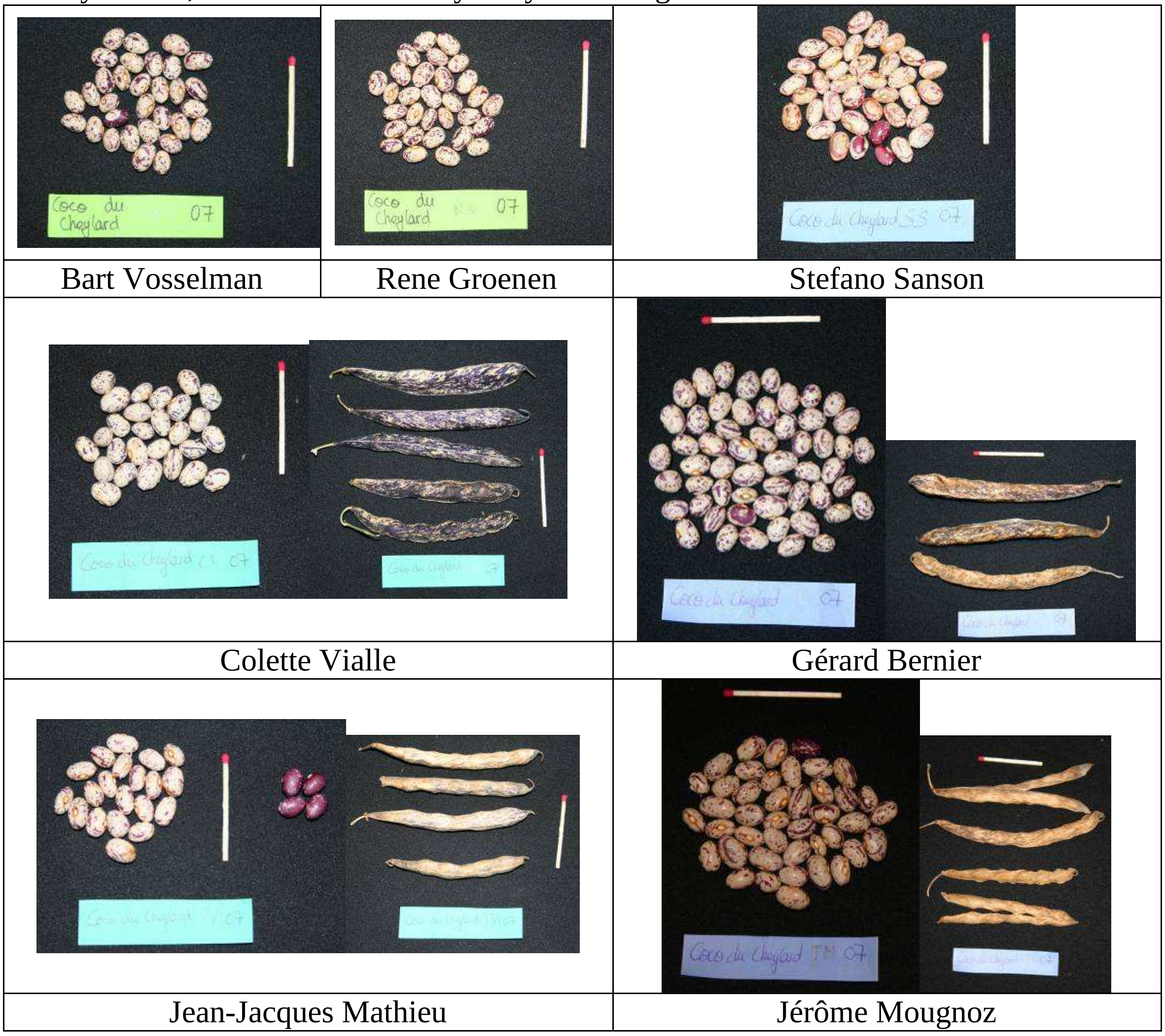
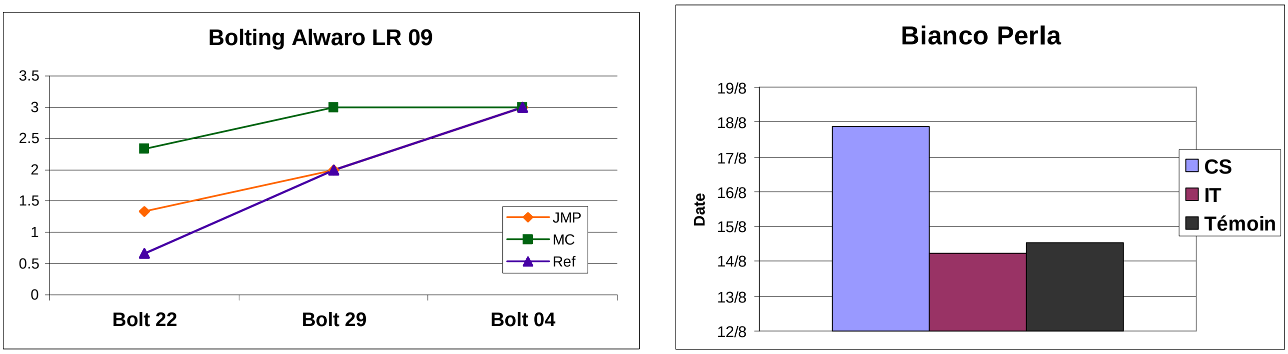


Figure 5: Seed and pod observation for seven samples of the variety Coco du Cheylard harvested in the 2007 on-farm experiment.

Stability in time: In the common experiment at le Rheu 2009 as well as in the on-farm experiments, we found that for most of the characteristics measured, phenotypic expression had changed (2nd generation versions from each farm vs initial / reference varieties). The evolution varied depending on the variety, the trait and the location where it was cultivated. Phenological traits such bolting time (e.g. for spinach in Figure 6), heading date or flowering time (e.g. for maize in Figure 6) often changed for the four species. This was expected since it is a major adaptive trait involved in climate response, and this experiment moved varieties drastically outside their usual climatic conditions. Thus, 2-3 years of cultivation in contrasting conditions appeared to induce variations in phenotypic expression, including for the catalogue varieties (Figure 7). This is an indication that varieties tend to adapt to their new climatic conditions. Despite these changes in quantitative traits, however, each variety remained distinct and recognizable.



A. **B.**

Figure 6: **A)** Bolting curves (proportion – expressed by an index from 0 to 3 - of the plants bolted at 3 dates: 22 and 29th of May and 4th of June) for the spinach variety Alwaro (control – ref - and two versions – JMP and MC -) assessed at Le Rheu experiment in 2009. **B)** Male flowering date for the maize variety Biancoperla (control – Témoin - and two versions – CS and IT -) assessed in the Le Rheu experiment in 2009.

Some farmers explained that it takes 4-5 years for a landrace to adapt to the conditions on their farm; after this period, the population's performance stabilizes for agronomic traits, even while it stays heterogeneous at the individual plant level. The length of this project did not allow for the evaluation of this facet of phenotypic stability in farmers' fields, but this "stability" (buffering capacity, different from UPOV definition of stability) due to diversity remains a major reason farmers give for using landraces.

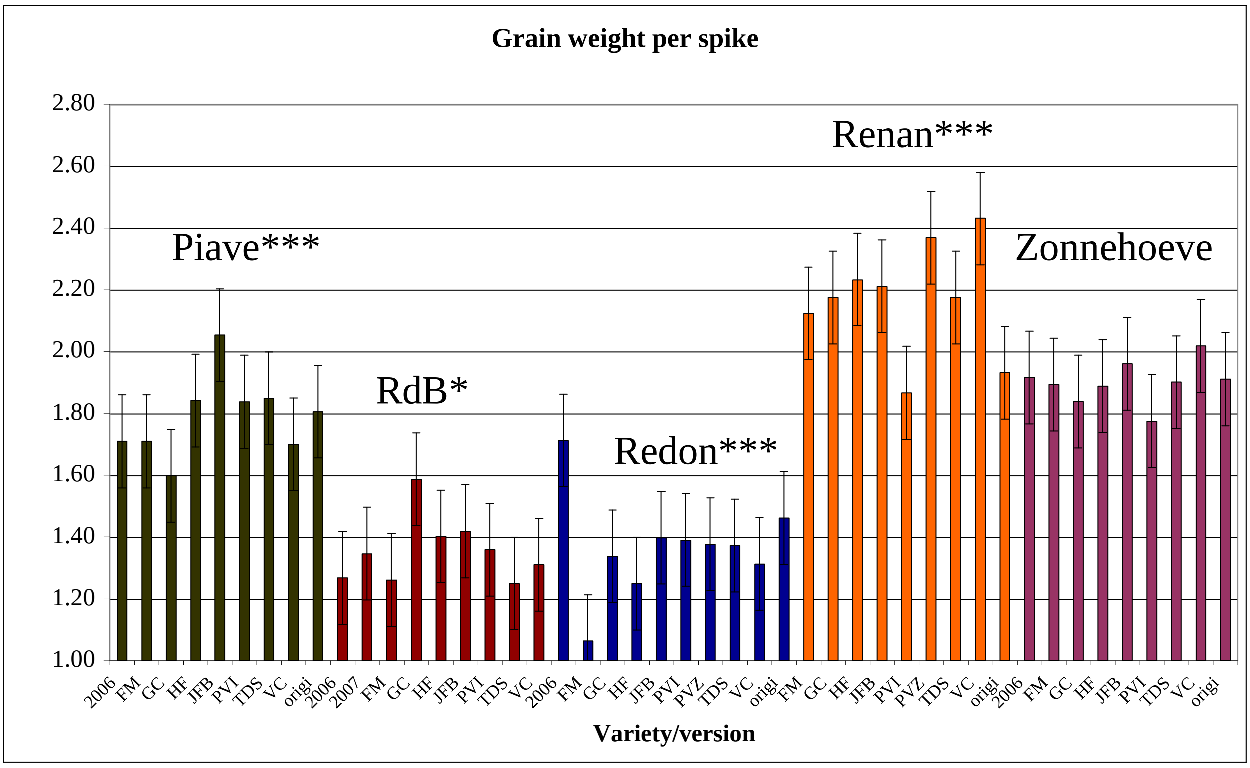


Figure 7: Grain weight per spike of the different versions of five wheat varieties with overall F-test, $p<0.0001$ for variety and version within variety.

Utilization of the UPOV criteria of homogeneity and stability therefore appears to us to be inappropriate for describing conservation varieties or any other variety cultivated *in situ*; only the distinctiveness criteria appears to be useful and is not called into question by either the non-homogeneity or the non-stability of these varieties.

2.4 Limited Geographical Zone

Some landraces gave very good results, sometimes even superior results, for certain productivity traits outside their zone of "origin" or "natural adaptation". Therefore, limiting cultivation of these varieties to a narrowly defined geographic zone would limit farmers' choice of and access to potentially interesting landraces and historic varieties. In addition, the reduction of permitted cultivation to a legally defined geographic zone for conservation varieties would favour the increased genetic erosion of these varieties both by limiting population numbers and sizes and by limiting the range of environmental conditions to which the variety is exposed (thus constraining their evolutionary potential).

2.5 Genetic erosion

The results of a study conducted on the dynamic management of wheat populations (INRA) showed that a network of on-farm sites can maintain overall genetic diversity as long as the sites and cultivation practices are diverse (metapopulation principles). Another study on the Rouge de Bordeaux variety conserved in the French farmers network (RSP) showed the complementary nature of *in situ* dynamic management and conservation in the national genebank. While samples conserved in the genebank only captured and maintained a small part (often a single genotype) of the diversity initially present in a landrace, the evolution and adaptation that can develop after many cycles of cultivation *in situ* in contrasting conditions permits the diversification and the maintenance of the evolutionary potential of a variety.

2.6 Farmers' practices and competence

This experiment was not focused on assessing farmers' practices and competence but rather on variety evolution. Yet, the strong interactions between farmers and scientists brought to light some specific examples of farmers' expertise. For three species, they conducted specific selection within and/or among varieties which yielded in some cases a very good selection response. For instance, a Dutch farmer (AVO) selected a spinach variety only for late bolting and flowering. In the Le Rheu trial, this version of the Monarch Long Standing changed very little for morphologic traits (quantitative and qualitative), but had significantly evolved for developmental traits in the expected sense. In addition to selection practices, farmers were strongly aware of seed sanitary and quality issues and accordingly they made choices in terms of seed management practices. Yet, the FSO trials were, for the most part, not treated as seed production tests by the farmers, but instead as an interesting means to try a diverse range of varieties and so they were less stringent in terms of the phytosanitary requirements that they normally use when producing seed for their own use of for exchange. For instance, during the first year of trials, several farmers detected viruses in the bean seed lots of different varieties they had received. Some farmers decided to eliminate the plants with viruses in order to prevent contamination and others did not. Interestingly, in year 2 and 3 neither the trials where farmers had suppressed infested plants nor the trials where they had not were contaminated. It was suggested that the virus susceptibility was in fact a response to the change of environment of the varieties. Farmers also noticed that two varieties had a poor germination rate in the first year. After one generation, the seed harvested for those varieties had a very good germination rate. These phenomena were regarded as indications of varietal acclimatation.

3 Conclusion

This study has shown the potential of on-farm management and selection of non-conventional varieties with respect to different objectives. Major conclusions include : (i) conservation of genetic diversity within and among landraces can be achieved in a very efficient way by on-farm management ; (ii) landraces and other non-conventional varieties are a source of interesting material for farmers under low-input or organic conditions; (iii) farmers practices for the management of the varieties and seeds may lead to better adaptation of the populations under their conditions.

To allow these positive aspects of on-farm conservation and breeding to fully develop, there is a need to make the seed regulations on conservation varieties more flexible in terms of the descriptive criteria (as the standard DUS criteria are not relevant in terms of uniformity and stability), region of origin and definition of the risk of genetic erosion. In addition, other non-conventional varieties that do not fit into the category of conservation varieties, such as new population-varieties or mixtures created by farmers, need to find an appropriate legislative framework.

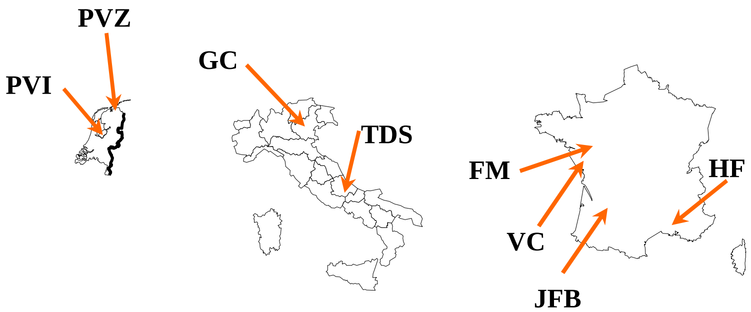
Annexes

3.1 Annexe 1: Wheat varieties and on-farm experimental design

List of the 10 wheat varieties studied with their origins: eight are “non-conventional varieties” (landraces, old varieties and new farmers varieties) and two are modern registered varieties.

	Variety	Farmer	History
	French		
HL	Haute-Loire	FM	Landrace from the mountainous region of central France, cultivated on farm for two years.
RD	Redon	NS (trial lost)	Mixture composed by a farmer from different landraces from Brittany.
RB	Rouge de Bordeaux	JFB	Historic variety (1880) from SW France continuously cultivated on farm.
TO	Touselles	HF	Mixture of 4 different Touselles landraces (middle ages) including one *T. Turgidum*, cultivated on farm for around 10 years.
	Dutch		
ZW	Zeeuwse Witte	PVZ (trial lost)	Old landrace from the SW of the Netherlands cultivated on farm since 2005.
ZH	Zonne-hoeve	PVI	Mixture of two modern German varieties cultivated on farm it in a Polder for more than 10 years
	Italian		
SO	Solina	TDS	Landrace from the Abruzzo region (center of Italy) continuously cultivated in its region of origin
PI	Piave	GDC	Landrace from the Veneto region (NE Italy) provided by the IGSA di Vicenza
	Modern		
RN	Renan	France	Commercial modern variety (INRA) known as the reference for OA
AU	Aubusson	France	Commercial modern variety (Nickerson)

Design for on-farm wheat trials in the Netherlands, France, Italy.

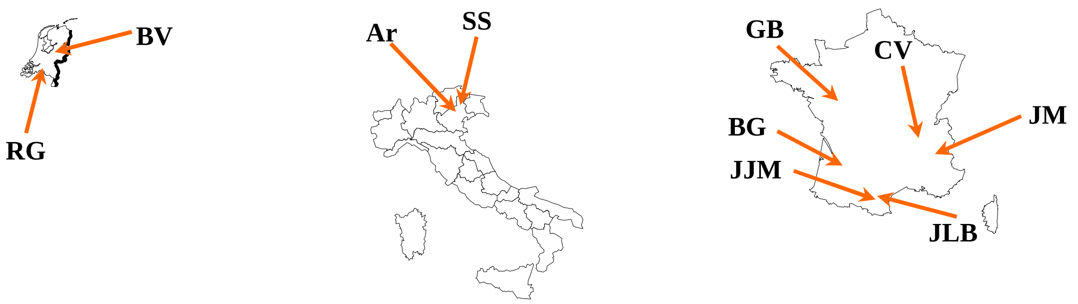


3.2 Annexe 2: Bean varieties and on-farm experimental design

All bean varieties are farmers' varieties either given by farmers for French and Italian varieties or by an associative genebank for the Dutch ones.

	The Netherland		Italy			France					
	BV	RG	Arsiero	Feltre	Abruzzi	GB	CV	JM	JJM	JLB	BG
Coco du Cheylard	●	●	●	●		●	●	●	●		●
Flageolet Chevrier	●	●	●	●	●	●	●	●	●	●	●
Gialet	●	●	●	●	●	●	●	●	●	●	●
Haricot Cerise						●	●				
Princesse de Chambord	●	●	●	●	●	●	●	●	●	●	●
Rouge Suisse	●	●	●	●	●	●	●	●	●		●
Scalda	●	●	●	●		●	●	●	●		
Walcherse Witte	●	●	●	●		●	●	●	●		●
Waldbeantsje	●	●	●	●			●	●	●		●

Design for on-farm bean trials in the Netherlands, France, Italy.

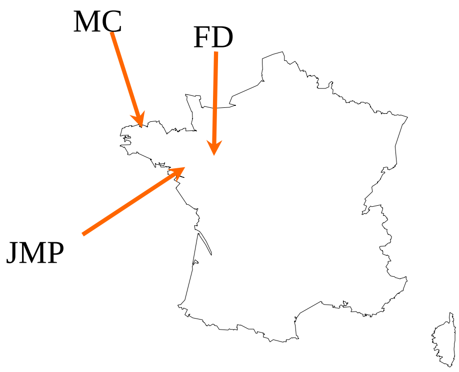


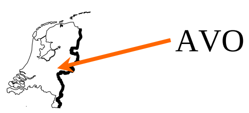
3.3 Annexe 3: Spinach varieties and on-farm experimental design

List of spinach varieties and their origins:

Variety	Precocity	Type/selection (if available)	Origin of the seeds
Hollandia	early spring	Old variety,selection of Swedish variety, which itself is a selection of Breedblad Scherpzaad Zomer	CGN
Verbeterde Hollandia	early spring	Selection of Breedblad Scherpzaad Zomer	CGN
Vroeg Reuzenblad	early spring	Selection of Breedblad Scherpzaad Zomer	CGN
Breedblad Scherpzaad Zomer	early spring	Old basic variety	CGN
Proloog	early spring	Kw.r.:1958	CGN
Resistoflay	early spring	American type	CGN
Duetta	early spring	Cross between Geant d'Hiver and Cavallius	CGN
Pre Vital	early spring	Selection of Resistoflay	CGN
Spinoza	normal spring	Selection of Resistoflay	CGN
Virtuosa	early spring	Kw.r.:1963	CGN
Amsterdams Reuzenblad	medium early	Introduction in 1886	CGN
Advance	medium early	Selection of Noordland Kw.r.:1951	CGN
Viking	medium early/ summer	Introduction in 1932; cross between ViroflayxKing of Denmark	CGN
Nobel	medium early/ summer	Introduction in 1926	CGN
d'été de Reuil	Spring		La semeuse (market)
Viking-Matador	Spring		Germinance (market)
Matador foncé			GEVES
Monstrueux de Viroflay			GEVES
Alwaro			GEVES
Supergreen			GEVES
Monarch Long Standing			GEVES

Design for on-farm bean trials in the Netherlands and France.





3.4 Annexe 4: Maize varieties and on-farm experimental design

Five varieties were grown on-farm in 3 different areas (Italy, Middle-West and South-West of France). Two varieties are Northern-East Italian traditional farm varieties (provided by IGSA) and three varieties are "French" population-varieties cultivated for several years in France by farmers of the association AgroBio Périgord.

Variety	*Description*
Biancoperla	It is very high and very healthy variety. Well homogeneous, not very vigorous. Long leaves, light green often coloured with red.
Italien	Heterogeneous, different types in the population.
Grand Roux Basque	Quite heterogeneous. Quite small, tendency to have 2 spikes. Broad spikes but not very long. The most early. Not very high nor healthy (compared to the others).
Narguilé	Quite high and globally quite healthy too. Good vigour. Tendency to have very high spikes.
Sponcio	Very homogeneous. Small yield. Very healthy. Quite high (spikes also). Foliage light green and not very erected.

Biancoperla and Sponcio (the Italian varieties) are still currently used in the region of Veneto for cooking Polenta, an Italian specialty.

Design for on-farm maize trials in Italy and France.