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Wheat landraces : action-oriented data for Pays de la Loire organic farmers.

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ABSTRACT

Cultivated biodiversity dramatically decreased along XXth century, what is especially true for tender wheat. In France farming systems, this disappearing is today manifested by inadequacy between certified varieties available and organic farmers requirements. To answer this needs, several groups of participatory wheat landraces breeding emerged along last decade. That is how Coordination Agrobiologique (CAB) initiated its breeding program in 2006, reproducing wheat landraces from botanic conservatory. CAB was thus an opportune structure to carry out this thesis, which purpose was to give field-oriented data on wheat landraces to help Pays de la Loire farmers choices of varieties. Notations for these last three years were gathered into 3 categories : weed suppressiveness, damage resistance (especially lodging) and economic profitability. These agronomic data were then completed by bread-making tests and sampling to foster use and diffusion of varieties bred in the program in regional food system. Even if it seems that wheat landraces are more suitable for poor soils than commercial seeds, almost no difference could be certified with more than 95% confidence. Firsts bread-making trials showed that there is not any specific problem to bake landraces when practices are adapted. Sampling results show that genotype (varieties) seem to influence bread taste less than bread-making practices and terroir effect. These results can be seen as new hypothesis that should be verified next years.

RÉSUMÉ

Le XXème siècle a connu une forte érosion de la biodiversité cultivée, ce qui s'illustre clairement par le cas du blé tendre. Dans les fermes françaises, cette disparition se manifeste aujourd'hui par l'inadéquation entre l'offre de variétés certifiées et la demande des agriculteurs biologiques. Pour pallier à cette demande, des groupes de sélection participatives ont émergé au cours de la dernière décennie. C'est le cas de la Coordination Agrobiologique (CAB) qui a initié depuis une dizaine d'année un programme de sélection participative, en multipliant des variétés de pays sorties de conservatoire. La CAB a ainsi été un lieu propice à cette étude, ayant pour but de procurer des données facilitant le choix par les agriculteurs des variétés à cultiver dans leur ferme des Pays de la Loire. Les notations des 5 dernières années ont été regroupées en trois grandes catégories : compétitivité face aux adventices, résistance aux dégâts des cultures (et plus spécifiquement : la verse), et à la productivité économique. Ces données agronomiques ont été complétées par des tests de panification et de dégustation en vue de faciliter l'utilisation et la diffusion de variétés du programme, faisant des variétés paysannes une clé de reconstitution des filières locales. Même si il semble que les variétés paysannes soient plus adaptées aux terres à faible potentiel, très peu de différence n'a pu être vérifiée statistiquement. Les premières expérimentation ont pu montrer que la panification des variétés de pays n'est pas un problème dans le cas de diagrammes appropriés et que les différences variétales influencent moins le goût du pain que les pratiques boulangères et le terroir. Ces pistes devront être confirmées et affinées au cours des prochaines années, notamment dans le cadre d'un programme CAB restructuré.

ACRONYMS

AB : *Agriculture Biologique* (=Organic Farming)
ANR : *Association Nationale de la Recherche* (=National Research Association)
ARDEAR : *Association Régionale pour le Développement Et l'Aménagement Rural* (Regional Association for Rural Development and Planning)
CA : *Conseil d'Administration* (= Board of Directors)
CAB : *Coordination des Agriculteurs Biologistes (des Pays de la Loire)* (=Coordination of Organic Farmers in Pays de la Loire)
CDA : Collectif pour le Développement de l'Agroécologie
COV: *Certificat d'Obtention Végétal* (= Plant Procurement Certificate)
COVm: Covering (mark)
CREAB : *Centre Régional de Recherche et d'Expérimentation en Agriculture Biologique* (=Regional Research Center in Organic Farming).
CTPS : Comité Technique des Semences et des Plants
DRAAF : *Direction Régionale de l'Alimentation, de l'Agriculture et de la Forêt* (= Regional Board for Food, Agriculture and Forestry).
EU : European Union
FAO : Food and Agriculture Organisation
FNAB :*Fédération Nationale d'Agriculture Biologique* (= National Federation of Organic Farming)
FOC : French Official Catalogue for Seeds and Young Plants
GABB : Groupement des Agriculteurs Biologistes et Biodynamistes (d'Anjou, du 44…)
GEVES : Groupe d'Etude et de contrôle des Variétés Et des Semences
GNIS : Groupement National Interprofessionnel des Semences
HCV : Height of Curved Straw (mark)
HTS : Height of Taut Straw (mark)
HOL : Holding (mark)
INRA : Institut National de Recherche Agronomique
InVS : Institut de Veille Sanitaire
ITAB : Institut Technique d'Agriculture Biologique
ITCF : Institut Technique des Céréales et des Fourrages
MFA : Multiple Factors Analysis
MSA : Mutualité Sociale Agricole
OF : Organic Farming
PCA : Principal Component Analysis
PdL : Pays de la Loire
PGRFA : plant genetic resources for food and agriculture
QDA : Quantitative descriptive analysis
RSP : Réseau Semences Paysannes
SHiNeMaS : Seeds History Network Management System
SW : Specific Weight
T. : *Triticum*
TKW : Thousand Kernel Weight
UAA: Utilised Agricultural Area
UPOV : International Union for the Protection of new Varieties of plants
VATE : Valeur Agronomic, Technologique et Environementale (=Agronomic, Technological and Environmental Value)
WL : Winter Losses (mark)

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1. INTRODUCTION

1.1. Worldwide global issues on seeds

Together with water and soil, seeds belong to farming basic resources. For this reason, mastering these resources is of primary importance for food sovereignty (FAO 1996). Seed monopolizing by private interest is a risk specially emphasized by the international treaty on plant genetic resources for food and agriculture (FAO 2009). The treaty mentions :

> *“ 6.2:The sustainable use of plant genetic resources for food and agriculture may include such measures as: [...]*
>
> *e) promoting, as appropriate, the expanded use of local and locally adapted crops, varieties and underutilized species;*
>
> *f) supporting, as appropriate, the wider use of diversity of varieties and species in on- farm management, conservation and sustainable use of crops and creating strong links to plant breeding and agricultural development in order to reduce crop vulnerability and genetic erosion, and promote increased world food production compatible with sustainable development; and*
>
> *g) reviewing, and, as appropriate, adjusting breeding strategies and regulations concerning variety release and seed distribution.”*

Until now, 139 countries contracted this treaty: France is one of those.

1.1.1. Socio-cultural importance of seeds

It is essential to understand seeds as a part of complex systems. Their influence on civilisation and vice versa can be pointed out through the process of co-evolution that led cultivated species during centuries. Old varieties are the result of a community selection rather than isolated farmers. Along generations, seed handover and exchanges were associated with a set of know-how to cultivate them in proper conditions, sometimes in a written way but mostly verbally.

What seeds produce in peasant communities is therefore more than food : they are part of the community and represent a transmissible cultural inheritance. Their specific place in initiation ritual, traditions associated to species, ritual and ceremonial uses, transmitted along generations within those communities is an evidence of this influence (Brac de la Perrière 2014). Food and Agriculture Organisation (FAO) underlines the importance of “traditional lifestyles and languages” across the globe to save genetic resources, justifying the need for greater attention to on-farm management of plant genetic resources for food and agriculture (PGRFA). (FAO 2010).

1.1.2. Cultivated diversity erosion

FAO reports also that public awareness is growing regarding genetic diversity issues. The increasing demand for greater dietary diversity and future production challenges require public attention to cropping diversity of species and varieties. This is expressively the case to face climate change which implies that in the future, “farmers and plant breeders will need to be able to access an even wider range of PGRFA than today.” (FAO 2010).

Genetic erosion
condition that results when a widely planted crop is uniformly susceptible to a pest, pathogen or environmental hazard as a result of its genetic constitution, thereby creating a potential for widespread crop losse
(FAO 1996)

Some examples can be found in literature to make out risks of threats (pest, pathogens, environmental hazard) for farmers due to genetic erosion. The largest global example is a one of the outbreak of UG99 race of stem rust, to which the large majority of wheat cultivated today is susceptible. Main causes of genetic erosion reported by countries are: “replacement of local varieties, land clearing, over-exploitation, population pressures, environmental degradation, changing agricultural systems, overgrazing, inappropriate legislation and policy, as well as pests, diseases and weeds.” (FAO 2010). Dahl and Nabhan add to this list : “Loss of seed-saving and vegetative propagation skills, acculturation (or death) of traditional caretakers, change in economic base, herbicides and pesticides impact, net reduction in the number of farmers and inadvertent crossing of varieties”. They portray modern varieties and exotic crops as the main factor of cultivated diversity erosion (Dahl and Nabhan 1992).

In FAO's report on the state of the world biodiversity, countries reported some specific case of genetic erosion, gathered by categories in table 1.

Table 1: World genetic erosion reported cases (FAO 2010)

Crop group	Number of countries reporting genetic erosion
Cereals and grasses	30
Forestry species	7
Fruits and nuts	17
Food legumes	17
Medicinal and aromatic plants	7
Roots and tuber	10
Stimulant and spices	5
Vegetables	18
Miscellaneous	6

Among opportunities to foster crop diversity, the most important are “fragmentation of farm holdings, allowing farmers to maintain landraces in at least one field, increasing cultivation of marginal land, where landraces tend to have an advantage over modern varieties, economic isolation, creating market distortions which give landraces a competitive advantage and cultural values and preferences for diversity” (Brush 1993).

1.2. French wheat selection

1.2.1. History and definition

In France, the biggest changes for wheat selection practices occurred along the last century.

Before, French farmers mostly used landraces with high intrinsic genetic diversity (Goffaux and al. 2011) what can be proofed by relatively low calculated Gst[1] (Dreisigacker et al 2005; Jombard et al. 2010; Zhang et al 2006). These old landraces have formerly been described by some botanists, agronomists and breeders.

Still in the XIXth century, a variety was defined as a set of genotypes of a same species cultivated and co-evolving in a same area showing more or less similar genetic heritage (what we call “landrace”). Homogeneity of characters among individuals of a same varieties became stricter since the International Union for the Protection of new Varieties of plants (UPOV) gave its own definition. This testify a change of selection paradigm of the XXth century.

At the end of the XIXth century, some varieties of interest (essentially for their agronomic performances) have been imported from Ukraine (e.g *Noé*) and England (e.g. *Chiddam d'Automne*, *Prince Albert*, *Victoria*) to France. These varieties started to be cultivated in minority by French farmers whose selection (97% of on-farm seeds reproduction still in 1945) and cropping practices let space for heterogeneity of characters. The absence of strict regulations on varietal purity could led a varieties sold by Vilmorin in 1904 (e.g. *Bon Fermier*) to present quite different genetic pattern after on-farm management by a farmer during 20 years. The term “old lines” aims to emphasize this aspect (Goffaux and al. 2011).

Between 1912 and 1964, genetic diversity within varieties decreased mostly because of increasing use of pure lines by French farmers. These pure lines were introduced by Vilmorin with the creation of the crossed varieties called *Dattel* (between *Chiddam d'Automne* with red ears and

1**Gst** is the portion of total genetic diversity (**Ht**) explained by the diversity between populations (**Dst**). *Gst = Dst / Ht* (Goffaux et al. 2011)

Prince Albert). Jonard described marketed varieties after 1920 as presenting almost always white, without spikes, medium loose to medium compact ears, with oval glumes mostly large and supple. They presented high productivity, low resistance to brown and black rusts, to frost and medium precocity. Russian agronomist Flaksberger even introduced a specific ecotype *Triticum gallicum* to make out specificity of French varieties (Jonard 1951).

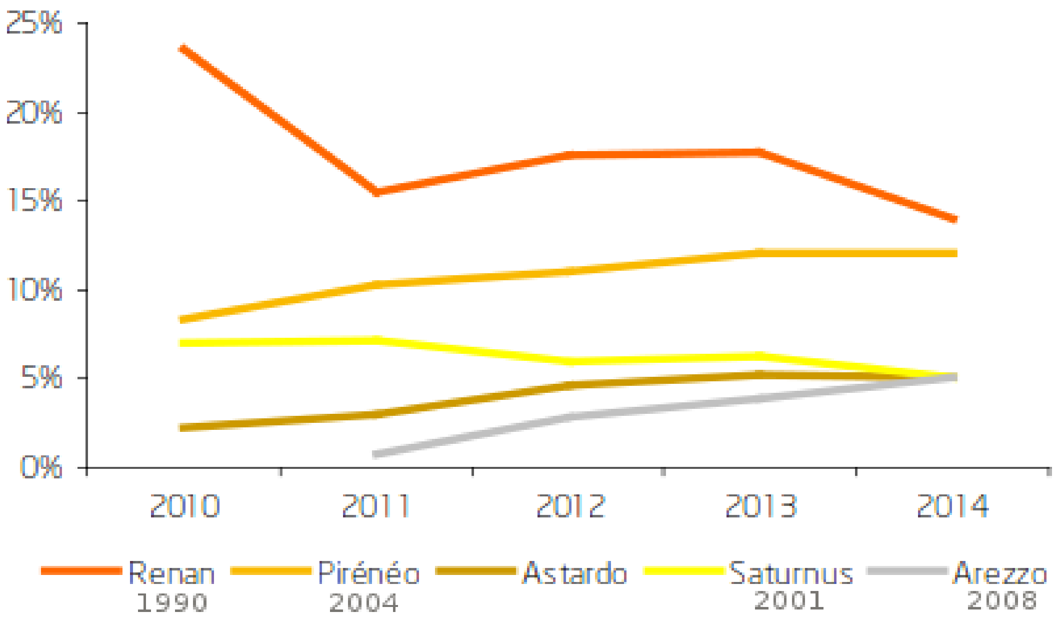
The creation of Comité Technique des Semences et des Plants (CTPS) in 1942 and its stricter codification led gradually to an even higher degree of homogeneity of lines (reducing diversity within varieties): we refer to them as “modern pure lines”. (Goffaux and al. 2011). We can especially point out prerequisite of “Distinction, Homogeneity, Stability” and “Agronomic and Technology Values”, called respectively DHS and VAT, to sell seeds.

At the beginning of 80s, genetic diversity erosion observed is mostly due to standardisation between varieties. At this time, landraces disappeared from French fields, subject to rare exceptions (CAB 2011). A final homogenisation of diversity between departments can be observed since the beginning of 90s (Goffaux et al. 2012). We can assume this last homogenisation to be a result of dramatic change of farming practices (and varieties bred in this context) during the second half of the XX[th] century.

Until today, we can exemplify this erosion of diversity by quoting some varieties such as *Cappelle* (1948), *Étoile de Choisy* (1951), *Capitole* (1964), *Soissons* (1987) and *Apache* (1998), whose cultivation widened from a few proportion of area cultivated in 1945 to 50% in 1970. Today, they almost disappeared from farmer fields. *Renan* is the most cultivated wheat pure line still in 2014 with 14% of organic UAA (France Agri Mer 2014)

Graph 1: Cultivated organic certified varieties in 2014 (% of national organic UAA)

Source : France Agri Mer 2014



1.2.2. Today organic needs

Since the 1st of January 2004, organic farmers are compelled to use organic seeds. However the supply of certified organic wheat seeds range is reduced and the varieties available are mainly bred for unchanging conventional farming conditions applying chemical fertilisers and plant protection products. For this reason, market varieties are no longer suitable to organic requirements (regarding weed suppressiveness, baking quality), as it is the case in other countries (Osman and al. 2016).

2014 FranceAgriMer survey shows that “quality” (35%) comes before “yields” (22%), “seeds availability” (16%) and “other agronomic feature”(15%) for the organic farmers interviewed. By “quality” is regarded “baking quality” through the millers assessment. Indeed, French marketed wheat is mainly sold for milling and baking for which “baking quality” is associated with “protein rate”. That's why advantageous bonuses are paid by millers to the organic farmers in case of high protein rate, explaining also the 35% interviewees looking for “quality” (FranceAgriMer 2014).

In “other agronomic features” are found adaptation to local climatic and soil conditions, adaptation to practices (such as two years wheat cropping), lodging resistance, rusticity and resistance to beast of prey (through spiked ears). By “rusticity” we can understand diseases and parasites resistance, weed competition, poor and dry condition resilience.

To face organic needs, some organic farmers from Pays de Loire got together with modern landraces breeding pioneers and participate to regional and national meeting (that's how Réseau Semences Paysannes was born in 2003) (CAB 2011).

As they have cultivated some landraces in their own field or gardens, these farmers underlined their high vegetative strength, their ability to compete with weeds thanks to their high straw. In comparison with marketed cultivars, their longer, thinner and outweighing number of roots enabling a better soil exploration and soil decomposers activity. Old landraces are also supposed to provide higher nutritional value, with higher levels of vitamins, minerals, trace elements and antioxidants (CAB et al. 2011).

Until now, benefits of population-varieties (including landraces) rather than pure line cultivation have been demonstrated regarding yields (Döring and Wolfe 2008), diseases like yellow rust (*Puccinnia recondita*), leaf rust (Goldringer et al. 2001) and powdery mildew (Enjalbert et al. 1999, Le Boulc’h et al. 1994).

A survey was conducted by Agence Bio between 2011 and 2012 on organic farmers motivations to sow population varieties (wheat, corn and sunflower seeds). The major point quoted is “context adaptation” (44%) followed by “contribution to autonomy” (33%), seed cost (29%), “quality” (20%) and “promoting biodiversity”(16%). For them, quality is defined by organoleptic and nutritional quality of products, completed by an agronomic point of view: “high straws, more organic matter for soil and cattle”(CAB 2014), justifying the purpose of our work.

We can finally emphasize that diversity of colour and shapes between different landraces enables farmers to recognize themselves has integrated in their local community and to see beauty and values emanating from their activity (Vindras-Fouillet et Chable 2014 (2)). Even if this dimension is hardly expressed through surveys, in a country where suicide - according to Institut de Veille Sanitaire (InVS) - is the 3rd cause of death within farmers (MSA 2015), it may be relevant to enlarge this field of study.

1.2.3. Incompatibility between organic farming and conventional seeds

Having described some issues related to landraces cultivation, legal context must be explained to understand its current situation in France.

1.2.3.1. Conventional seed breeding system

As explained on figure 1, in France a variety needs to follow a specific process to be registered in the French Official Catalogue for Seeds and Young Plants (FOC) and sold to farmers. In facts, a newly bred variety needs to be tested by the Varieties and Seeds Study and Control Group (GEVES) to estimate its “Distinction” from already certified varieties (D), its genetic “Homogeneity” between individuals (H) and over time (S, for “Stability”). Moreover, it musts provide sufficient agronomic and baking performances (Agronomic, Technology, and Environmental Value = VATE) to be categorised within the FOC. After publication to the French Official Journal and subscription, the varieties can be propagated in fields and finally sold with appropriated labels enabling authorities to control varieties/species purity, safety, and label of batches.

1.2.3.2. Unsuitability of landraces

Today, what prevent landraces to be registered are the costs of registration (6000€ + 2000€/year the 10 first years of publication) and aptitudes tested by the GEVES for new varieties submissions. As said earlier, landraces are often genetically diverse and context-adaptive, what goes against DHS standards presented previously. Moreover, the 2-3 years long VATE[2] testing, ensuring that the varieties submitted brings "progress" to the set of registered variety (CAB 2014), seems inappropriate to landraces which often show law baking strength (see W evolution on table 2).

Table 2: Appraisal of average W XX^th^ century evolution for tender wheat bred for common baking (Source : Roussel et Chiron 2001)

Années	1920-1940	1940-1950	1950-1960	1960-1970	1970-1980	1980-1990	1990-1997	1997-2001
W	60-80	80-90	90-100	100-110	110-130	140-170	180-200	160-180

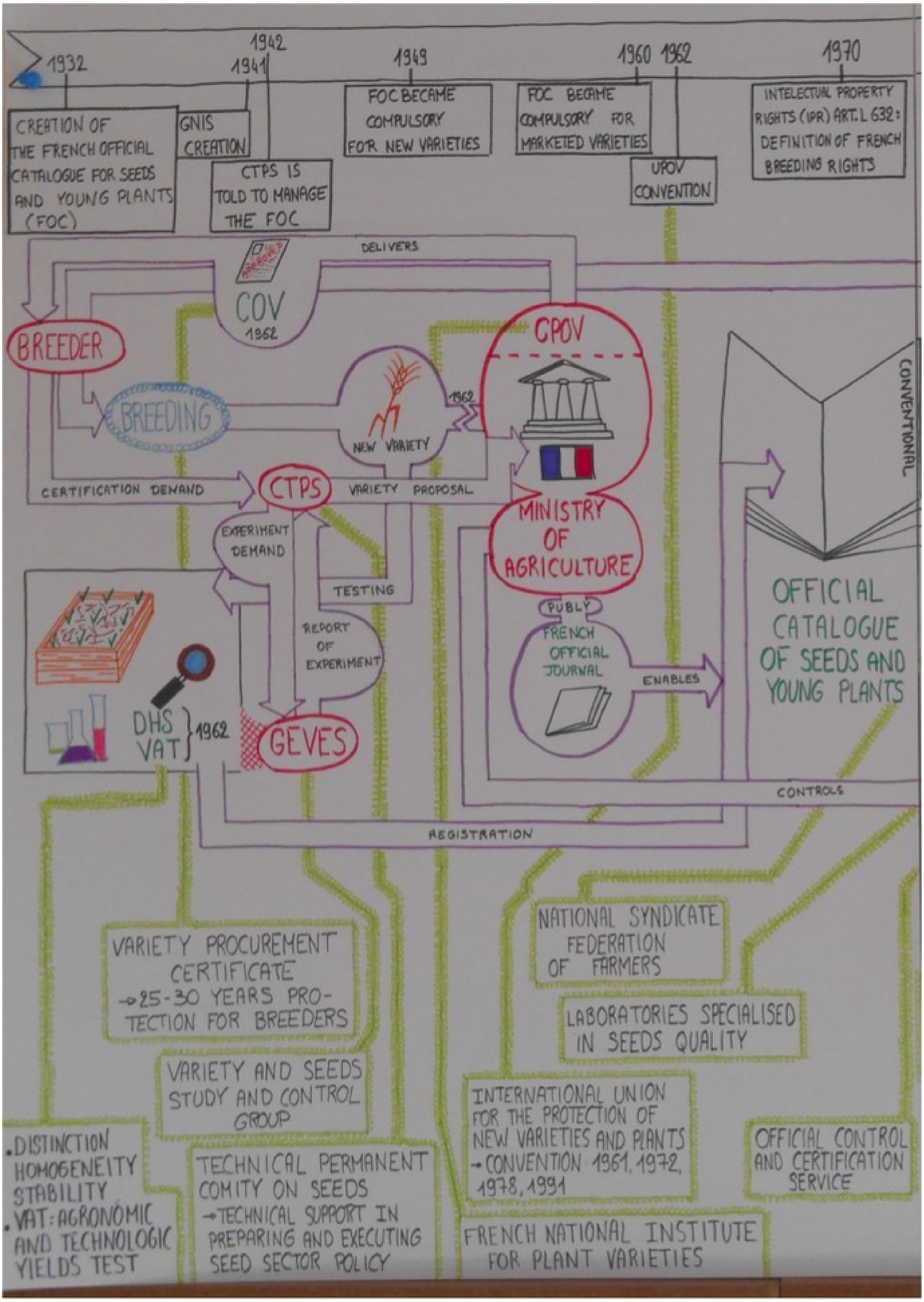
This is illustrated by BIPEA test, undertaking violent kneading (4 minutes of 1st gear and 15 minutes of 2nd gear on kneading machine), high fermentation speed (20g yeast /kg flour, between 2,5 and 3 hours fermentations), and mechanised shaping (Fontaine 2007) that cannot be supported by old varieties, mainly presenting low W index.

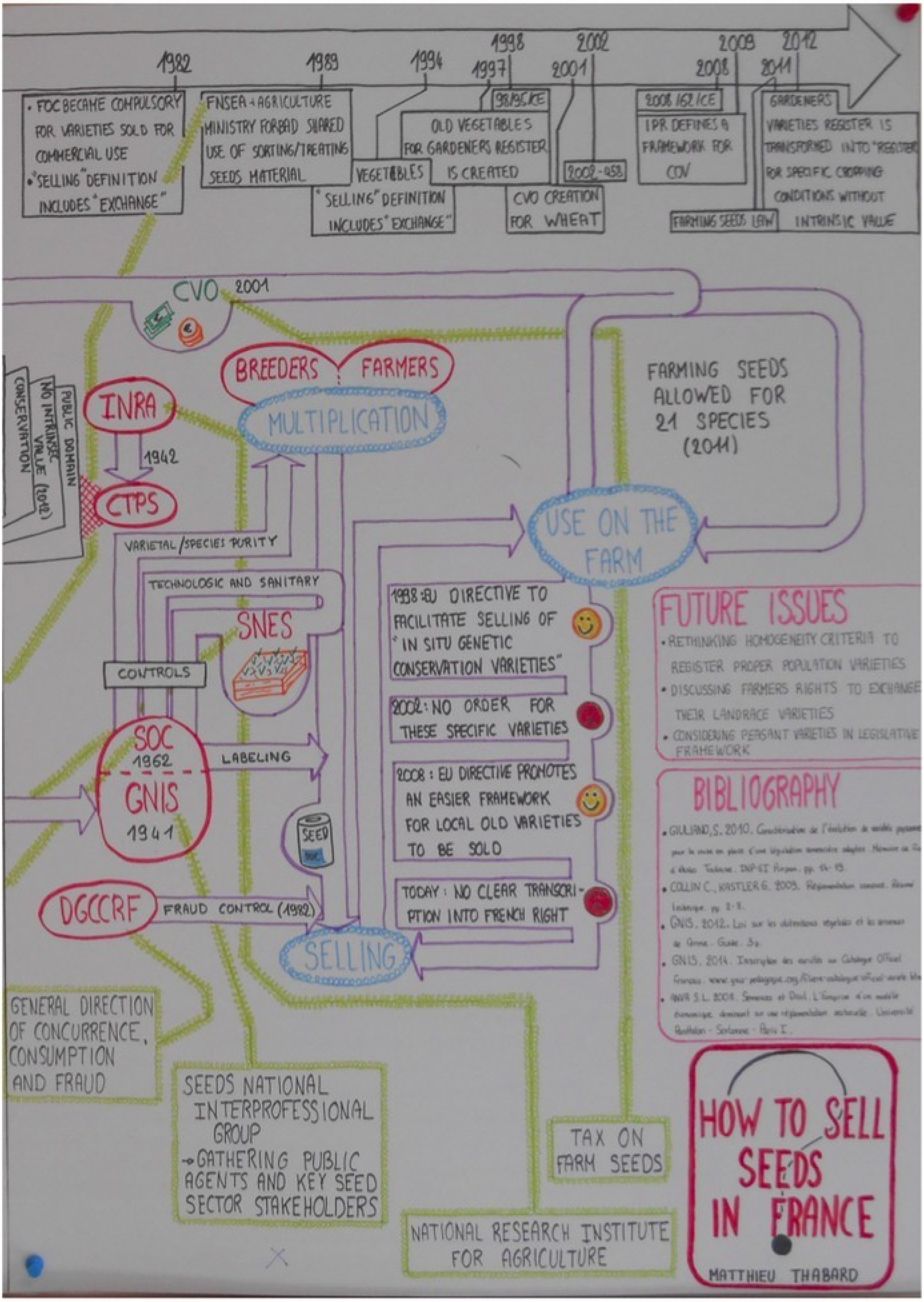
1.2.3.3. Recent changes in French legislation

Until July 2016, to sell their grains or bread, farmers were compelled to buy certified wheat varieties. Some exceptions could happen when farmers took part in a research program, such the CAB participative wheat breeding program. From 26th March 2014 was discussed in France a project of law regarding biodiversity (named *Project of law on recapture of biodiversity, nature and landscapes*). This text was modified twice by the national assembly and three times by the Parliament before its final adoption by the national assembly on the 20th July 2016 (Sénat 2016). Despite the seisin of the French constitutional council by the Parliament on the 21th July 2016, one officially adopted measure is essential for French legislation on seeds : From today, farmers are allowed to exchange uncertified seeds (Collectif Semons la Biodiversité 2016). Promoting wheat landraces diffusion, this measure will probably benefit organic farmers interest within CAB participative breeding program.

2 In figure 1, the figure mentions « VAT » instead of « VATE » because the Environmental factor of appreciation (« E ») has been added later.

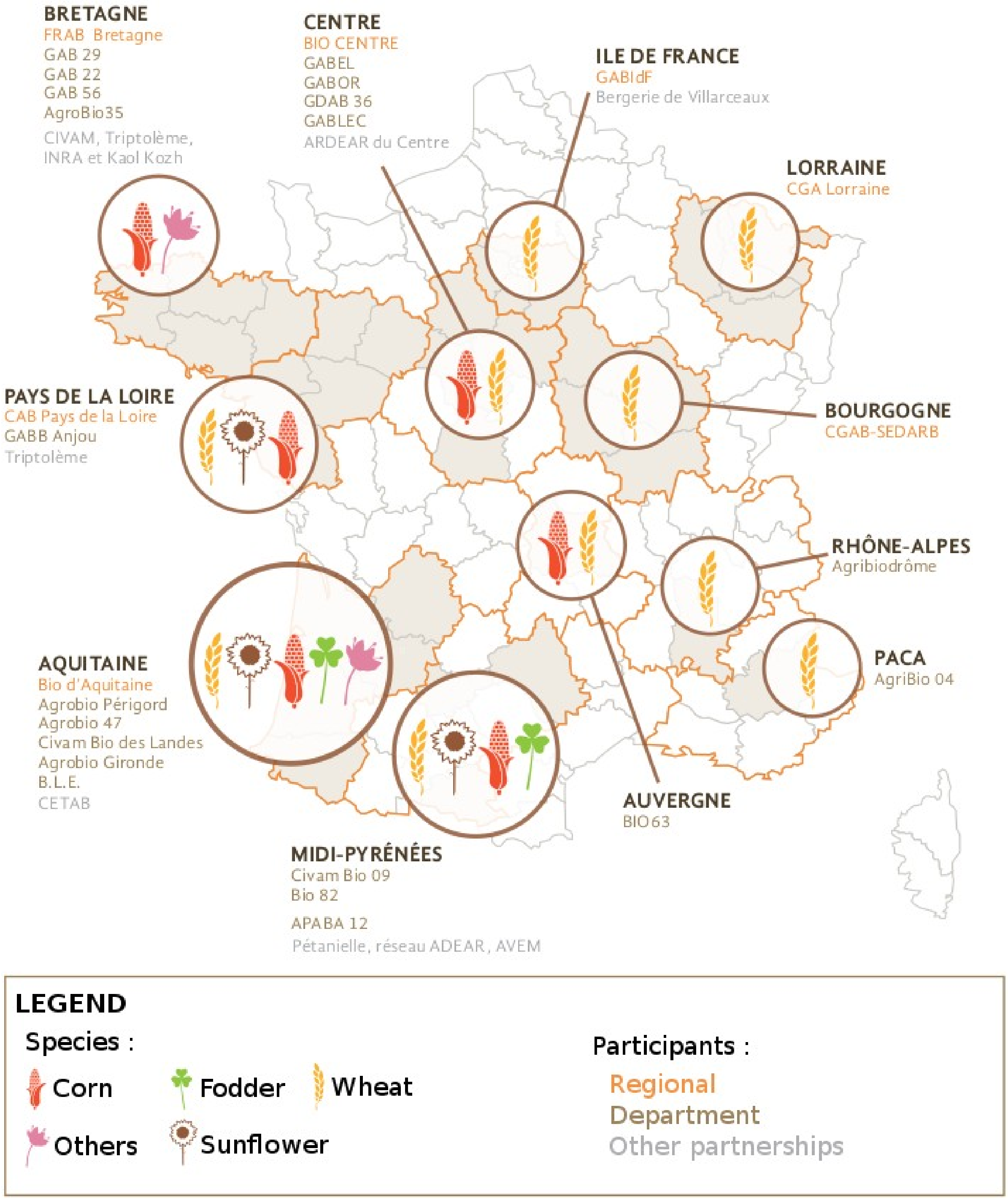
Figure 1: How to sell seeds in France ?




1982
1989
1994
1997
1998
2001
2002
2008
2009
2011
2012
• FOC BECAME COMPULSORY FOR VARIETIES SOLD FOR COMMERCIAL USE
• "SELLING" DEFINITION INCLUDES "EXCHANGE"
FNSEA + AGRICULTURE MINISTRY FORBAD SHARED USE OF SORTING/TREATING SEEDS MATERIAL
VEGETABLES
"SELLING" DEFINITION INCLUDES "EXCHANGE"
98/95/CE
OLD VEGETABLES FOR GARDENERS REGISTER IS CREATED
2002-453
CVO CREATION FOR WHEAT
2008/62/CE
IPR DEFINES A FRAMEWORK FOR COV
FARMING SEEDS LAW
GARDENERS VARIETIES REGISTER IS TRANSFORMED INTO "REGISTER FOR SPECIFIC CROPPING CONDITIONS WITHOUT INTRINSIC VALUE
CVO 2001
BREEDERS
FARMERS
MULTIPLICATION
FARMING SEEDS ALLOWED FOR 21 SPECIES (2011)
PUBLIC DOMAIN
NO INTRINSIC VALUE (2012)
CONSERVATION
INRA
1942
CTPS
VARIETAL/SPECIES PURITY
TECHNOLOGIC AND SANITARY
CONTROLS
SNES
USE ON THE FARM
1998: EU DIRECTIVE TO FACILITATE SELLING OF "IN SITU GENETIC CONSERVATION VARIETIES"
2002: NO ORDER FOR THESE SPECIFIC VARIETIES
2008: EU DIRECTIVE PROMOTES AN EASIER FRAMEWORK FOR LOCAL OLD VARIETIES TO BE SOLD
TODAY: NO CLEAR TRANSCRIPTION INTO FRENCH RIGHT
SOC
1962
GNIS
1941
LABELING
SEED
DGCCRF
FRAUD CONTROL (1982)
SELLING
FUTURE ISSUES
• RETHINKING HOMOGENEITY CRITERIA TO REGISTER PROPER POPULATION VARIETIES
• DISCUSSING FARMERS RIGHTS TO EXCHANGE THEIR LANDRACE VARIETIES
• CONSIDERING PEASANT VARIETIES IN LEGISLATIVE FRAMEWORK
BIBLIOGRAPHY
GENERAL DIRECTION OF CONCURRENCE, CONSUMPTION AND FRAUD
SEEDS NATIONAL INTERPROFESSIONAL GROUP
→ GATHERING PUBLIC AGENTS AND KEY SEED SECTOR STAKEHOLDERS
TAX ON FARM SEEDS
NATIONAL RESEARCH INSTITUTE FOR AGRICULTURE
HOW TO SELL SEEDS IN FRANCE
MATTHIEU THABARD

1.2.4. French initiatives on wheat traditional selection

Figure 2: Map of French initiatives on population seed breeding in organic cropping.



Sources : FNAB 2014

As illustrated by figure 2 many initiatives already started regarding landraces participative breeding. In order to structure data collected, a database called Seeds History Network Management Systems (ShiNeMaS) is up to be launched thanks to a cooperative work between

Réseau Semences Paysannes (RSP) and INRA team Diversité, Évolution et Adaptation des Populations (DEAP) started in 2003. This database aims to investigate and precise agronomic practices and exchanges impacts on tender wheat diversity structure.

There are also others initiatives regarding to other aspects of landraces, such as bread-baking. One major example is the *Bakery* program (French program linked to *DiversiFood* European Union (EU) research program). The two main objectives of this program are (ANR 2013) :

- to better understand the impact of different determinants on the biodiversity and functioning of the 'wheat/human/sourdough' food-agro-ecosystems,
- to think about the complementarity of ex-situ and in-situ conservation of wheat and microbial genetic resources.

Others initiatives poped up in several group of farmers and bakers to test bread-making. Among them we find Triptolème (2011), Pétanielle (since 2014), Association Régionale pour le Développement Et l'Aménagement Rural (ARDEAR) from Rhône-Alpes (2015), ARDEAR Nord (2015) and Collectif pour le Développement de l'Agroécologie (CDA) (2015).

Bread making issues are indeed essential for landraces expansion and very few studies were undertaken on this field. However, wheat marketed varieties influence on dough rheological properties has been frequently studied along last decades and this effect is well known nowadays (Roussel and Chiron 2001).

Focus on baking quality tests

Several tests are already available to test bread-making quality of different wheat varieties. Among them we find instrumental measures like infrared spectrometry (protein rate), Hagdberg falling number (amylase activity), Zeleny test (sedimentation index), gluten index and ash content tests. These tests provide objective data on wheat or dough features, but are expensive and difficult to interpret by bakers, especially those who have no technical formation, as it is sometimes the case of farmers who bake bread.

The test giving the highest quality of usable information is the bread-making test because it provides information about the whole process of bread-making. There are also several bread-making tests. The most famous one is the BIPEA test that is used to test varieties for FOC subscription. It is a test using violent methods (high kneading speed, quick fermentation, mechanical shaping) inappropriate to varieties cultivated before baking industrialisation.

The field bread-making trial consists in using practitioners baking conditions writing down conscientiously what these conditions are. The results can thus be interpreted methodically, considering the elements influencing them. This test is the mostly used to characterise old wheat varieties. Because economic value of such varieties is restricted to short-circuit transformation and selling, field-trials appears the most appropriate to integrate variations between baking environments.

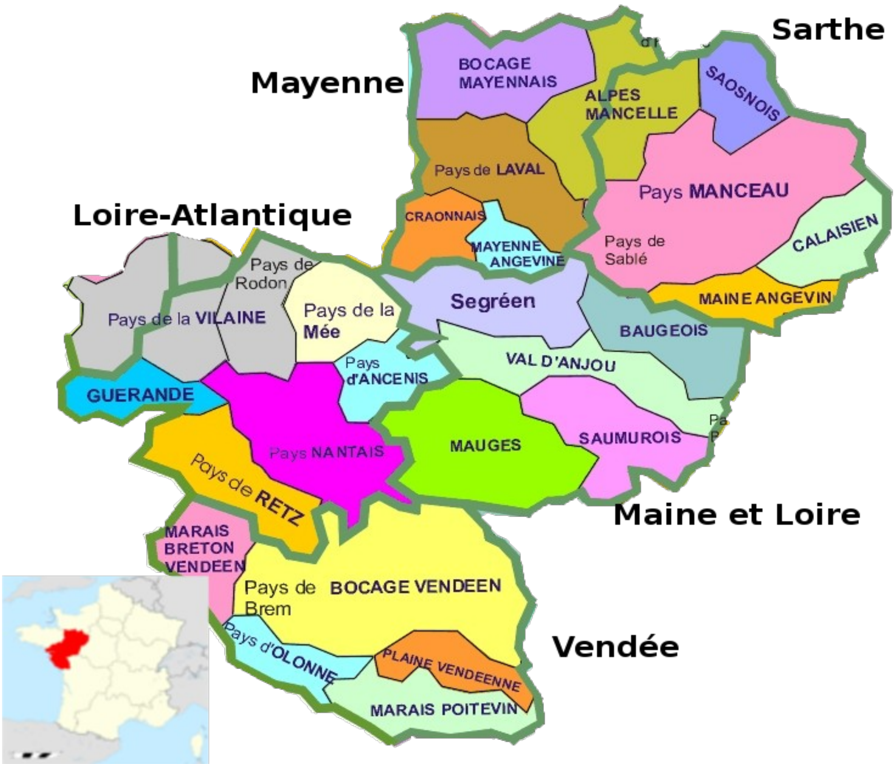
Because landraces are not profitable for conventional trade circuits, it appears relevant to foster local participative initiatives such as field bread-making to deepen our knowledge regarding old varieties.

Landraces promotion implies marketable abilities, what leads to consider bread taste and aspect. Wheat influence on bread taste has been very few studied until now and relative influence of baking process, cultivation context and varieties are still fuzzy. Recent interest for landraces open this field of study and state of experiments seems to show that varieties influence came after terroir and bread-baking process (Vindras-Fouillet and Chable 2014 (1)).

1.3. Pays de la Loire case

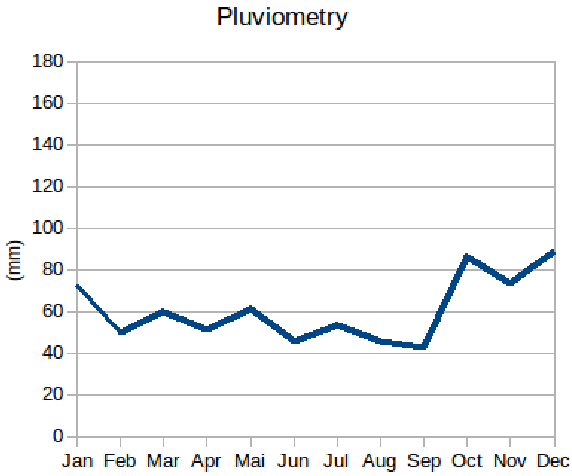
1.3.1. Pays de la Loire context

Figure 3: Pays de la Loire map



Located in the west of France, Pays de la Loire (PdL) region shows climatic difference between oceanic and territorial areas, even if oceanic influence (law temperature variation, mild winters, sunny summers and hard winds) globally prevail everywhere. Hills from Vendée and Mayenne get twice more pluviometry than Anjou, which is one of the driest area in France. Droughts and high temperatures are custom in the east, but PdL can also be subject to strong rains, snow or frost.

Graph 2: Annual pluviometry and temperature (2004 – 2013) in PdL (source : Agreste Pays de la Loire 2015).



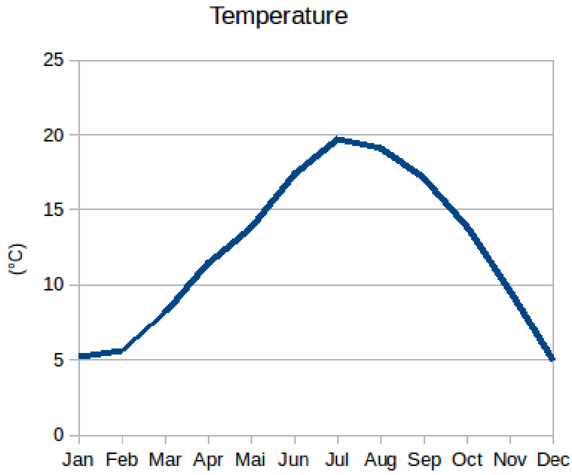
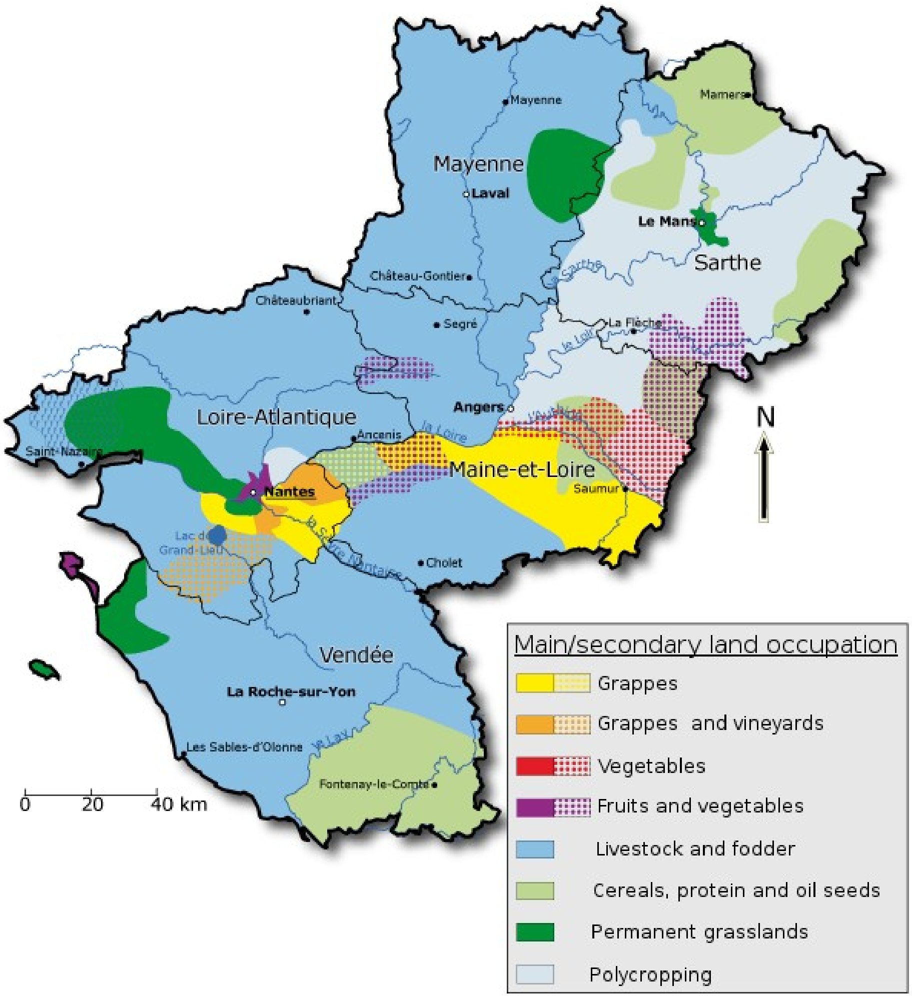


Figure 4: Land occupation in PdL (Source : Agricole census 2010, realised by ORES)



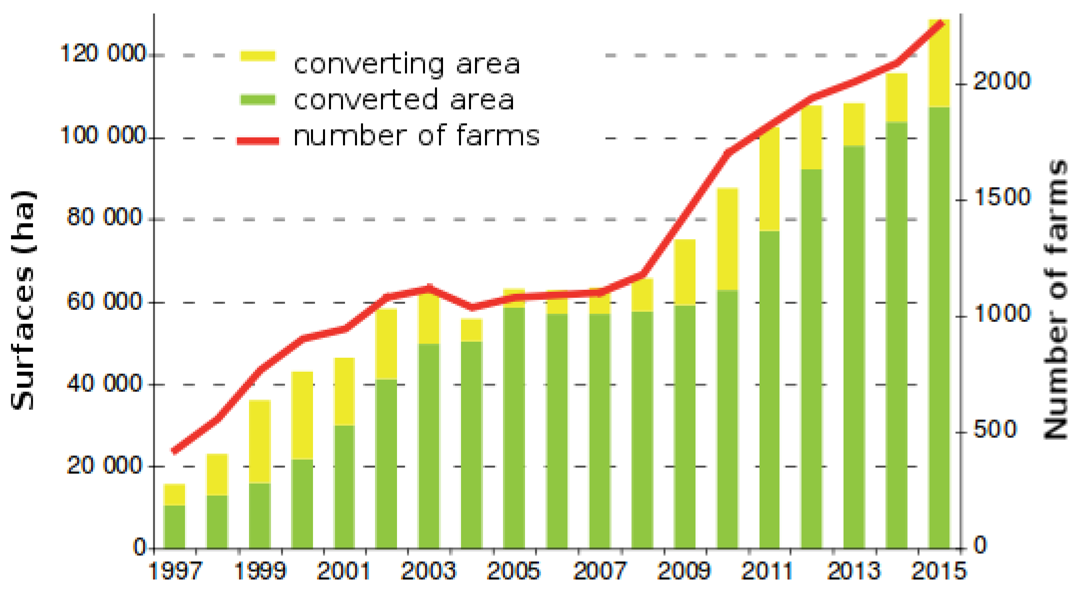
PdL region shows various type of soil conditioning the kind of farms in several areas (figure 4, ITAB 2011) :

- Limestone (mostly clay-limestone soils) : in the East of Maine-et-Loire , South-East of Sarthe, centre of Mayenne and South Vendée, where cereals, protein and oil seeds are produced.
- Silt : in the centre of Vendée, main part of Loire-Atlantique, North-West of Maine-et-Loire. Suitable for PdL livestock.
- Sand : on the coast of Vendée and centre of Sarthe. These soils have low water retention capacity implying drought resistant species cultivation.
- Wetland : on the Atlantic coast and in the South of Vendée. Cultivation is difficult on these soils : we find almost only permanent grasslands.

1.3.2. Organic farming in PdL

On the 12th of July 2010, the Grenelle environment forum setted goals for organic farming (OF) soil occupation. The first step was planed for 2012 at 6% of the French utilised agricultural area (UAA) and 20% for 2020 (in 2010, 2% of the UAA were cultivated by organic farmers).(Ministère de l'écologie, de l'énergie, du développement durable et des mers 2009).

Graph 3: Evolution of organic farming in PdL between 1997 and 2015 (Source : DRAAF 2016)



Today, as showed on figure 12, with 126 500 hectares certified Agriculture Biologique (AB is the French acronym for OF) or in transition from conventional systems, PdL is the second-ranked region regarding this aspect. This area is also expending : +8,7% growth between 2014 and 2015. If we consider the whole PdL UAA, organic and converting area represents 6% : 6th national rank for this aspect (behind locations where mechanised practices are difficult such as mountainous regions). (CAB 2016).

Table 3: Figures for PdL OF (AB certified or in-conversion)

Aspect	Figure	National rank (2015)
Area	126 500 ha	2
Number of farms	2 227	6
Proportion area	6 %	6
Food processors	784	5
Sellers	201	7
Milk volume production planed for 2017	150 million	25 %
Suckler cows	3 050	23 %
Sows	2 000	23,5 %
Poultry production area	120 000 m²	22 %
Vegetables production area	1 900 ha	8 %
Wineyards area	2 900 ha	8 %

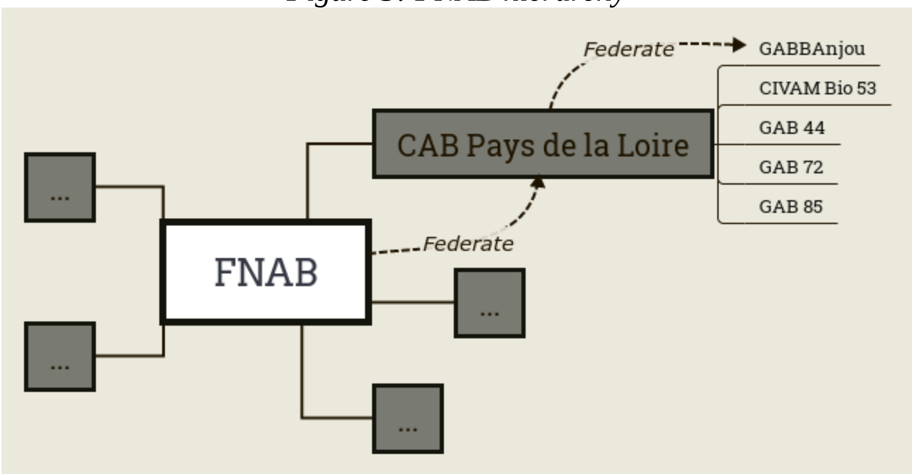
Indeed, the 2015 economic context was favourable for OF development:

- Organic prices stayed stables while conventional ones weren't (price decreasing, uncertainties for meat and milk products)
- Constant growth of organic product demand.
- Grants allocation secured for organic conversion or maintenance until 2020.

This development operates in several farming sectors, mainly through cattle farming for organic meat (49% of the in-conversion area) and milk production (19% of in-conversion area). Vegetable farming represents the first sectors regarding to new farms creations (19 farms created in 2015). We can see a 770ha growth of organic arable crops cultivated for selling, what can seem quite low regarding the 10 000ha in-conversion area. However, this figure is significant in PdL, where 70% of cereals and oil protein crops are supposed to feed animals directly on the farm. (CAB 2016).

The beginning of 2016 let envision even more dramatic increases of organic farming areas (+21% organic area expected) (CAB 2016).Such a development requires networking, technical and economic training means for new or interested producers to manage their land and/or breeding. That is the purpose of organic federating organisms such as Groupement des Agriculteurs Biologistes et Biodynamiste d'Anjou (GABBAnjou, departmental scale), Coordination de l'Agriculture Biologique des PdL (CAB, regional scale) and Fédération Nationale d'Agriculture Biologique (FNAB, national scale, founded in 1950) as described on figure 5

Figure 5: FNAB hierarchy



More precisely, GABBAnjou is a professional federation defending organic and biodynamists farmers from Maine-et-Loire since 1982. It aims to help these farmers to produce organic goods, to foster OF in the department, and to communicate on issues of OF to general public. This syndicate is supervised by a board of directors composed by elected farmers and supported by a team of employees (GABBAnjou 2016).

CAB was created in 1991 to gather the departmental network of PdL region (GABBAnjou, GAB44, CIVAM Bio Mayenne, GAB 72 and GAB 85). That's why representative of each departmental network are elected to participate to CAB directory board. Its goals are then linked to those of belonging departments to pass it toward regional level. Namely : “To represent organic production in politic and administrative institution, promote OF and its techniques, propose technical support to organic farmers, link OF with water quality issues, ensure business security and financial support of organic farmers” (CAB 2016).

1.3.3. **CAB program**

1.3.3.1. Program purpose and design

CAB participative breeding program started with one observation : most of the cultivated wheat area were occupied by only one variety (*Renan*). When it started, Renan[3] occupied almost one third of the whole organic area in France. Since 2000, some others varieties - specifically bred for organic condition - came from Switzerland and Austria (among them we find *Capo, Ataro, Pireneo* and *Ludwig*). These varieties, higher and better ranked by millers, were at this time the only alternative to short varieties proposed by the French Official Catalogue for Seeds and Young Plants (FOC).

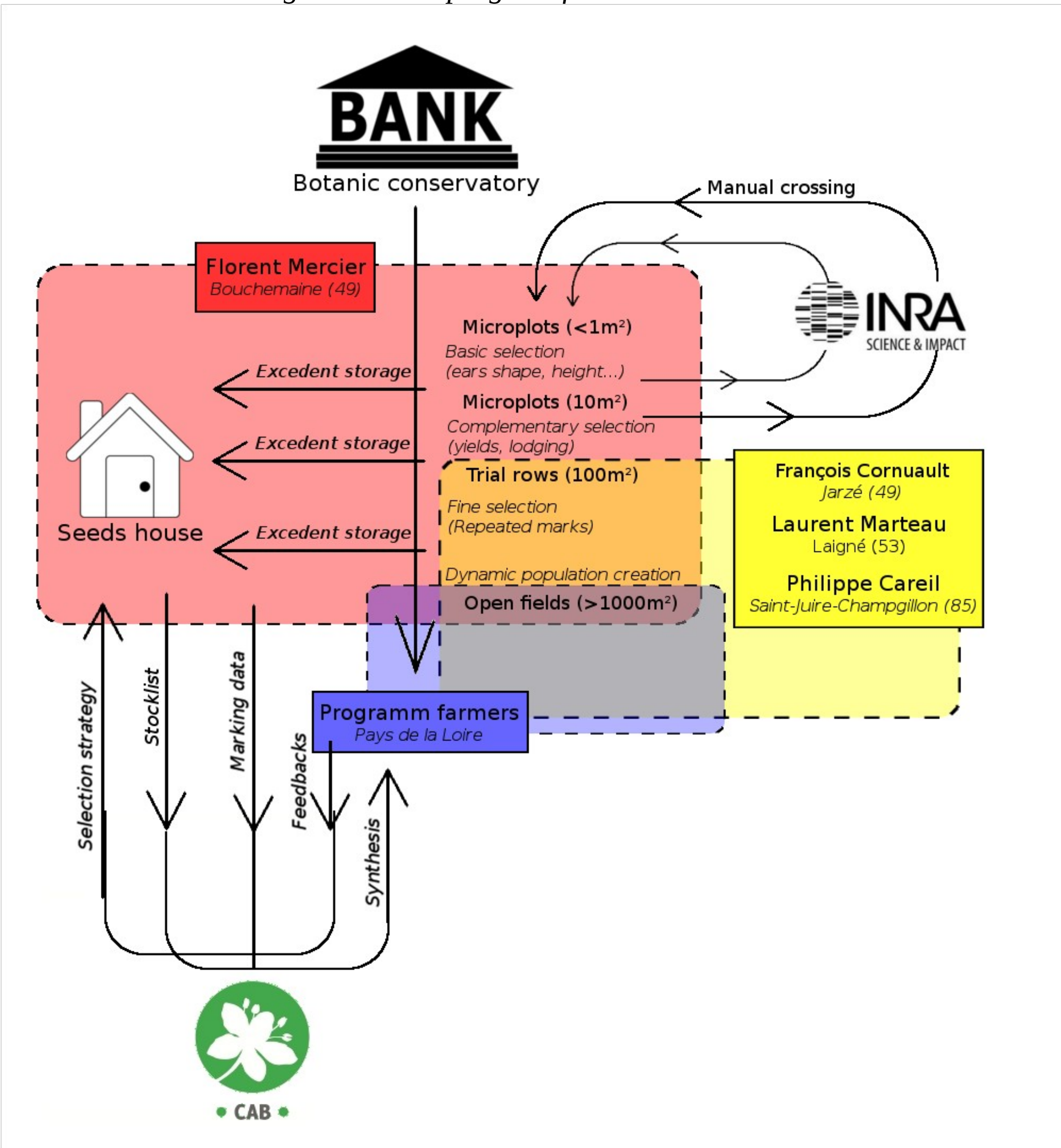
The "Cultivated species and biodiversity program : data acquisition and participatory breeding in PdL" was launched by the CAB in 2006. It still aims to:

- Promote biodiversity in PdL farms with :
  - Landraces adapted to the regional OF systems
  - Varieties adapted to processors needs, who are (in the case of wheat) mostly farmers processing their grains into bread or pasta.
  - A large range of cereal species including :
    - free-threshing (or naked) species like tender wheat (*Triticum aestivum subsp. aestivum*), durum wheat (*T. turgidum subsp. durum*), naked einkorn wheat (*T. sinskajae)*, naked zanduri wheat (*T. militnae)*, persian wheat *(T. turgidum subsp. carthlicum)* and rye (*Secale cereale*).
    - hulled species such as einkorn wheat (*T. monococcum subsp. Monococcum*), poulard wheat (*T. turgidum subsp. turgidum*), emmer wheat (*T. turgidum subsp. Dicoccum*), zanduri wheat (*T. timopheevi*), barley (*Hordeum vulgare*) and oats (*Avena sativa*).
- Foster farms independence from seed companies
- Help farmers managing production costs (seeds purchase costs represent 30% of the total added-value).
- Provide local farmers with organic or landraces seeds

To describe varieties precisely, select interesting ones (partly mixing them into dynamic populations), renew seeds stock, and provide a pedagogic framework, the program is articulated between a collection (microplots), pilot sites (trial strips), and field experiments (open-field), as explained on figure 6.

3 Renan is a variety obtained by INRA in 1989. Its rusticity, baking quality and vegetative development in comparison with other marketed varieties explains its increase in organic farmers fields since this date.

Figure 6: CAB program functionnal scheme



1.3.3.2. Collected data

To achieve these objectives entails markers definitions adapted to organic needs (presented above in part 1.2.2). Descriptors were fixed at the beginning of the program and completed along years through discussions between program supervisors and farmers.

Weed suppressiveness

Some studies already stressed out several variables regarding weed suppressiveness (or weed competition) explanation. One of them (study on wheat competition against rye-grass) shows that wheat height at maturity appears to be the first explanatory factor of weed suppressiveness, followed by *covering* (COV) and *holding* (HOL), even if predictability of characters differs between contexts (Arvalis 2013).

In some case however, wheat density after winter can explain a significant part of weeds competition (Bernicot et al. 2010) and it appears thus relevant to mark winter losses (WL) through a selection program, especially in organic context as in this study.

Because there is no correlation between height and covering power of varieties, these two factors need to be considered separately for light competition (Arvalis 2013). We such proceeded *covering* (COV), *height in april* (APR), *may* (MAI) and *at maturity* (HCS) marks.

Adaptation to the environment

Precocity : As exposed earlier, one major objective in cultivating landraces for farmers is to have varieties adapted to their farming system (e.g. soil, climate, practices). For this purpose, some farmers create population varieties. Earliness of each variety was ranked by measuring their ear emergence date, enabling farmers to choose varieties having relatively close earliness to plan population sowing/harvest easier.

Terroir / year effect : In agriculture, varieties is obviously not the unique factor of variation. Abiotic factors (soil, climate) and farmers practices (tillage, rotation, manure) can bring high variation. It is therefore essential, as well as varieties descriptions, to test influence of years and lands for which data were acquired.

Damages resistance

Lodging : Because lodging is one of the standard orienting farmers choices in varieties selection (part 1.2.2) and because it is one of the weak points often mentioned by farmers regarding landraces, it was decided to conduct lodging notations. *Height of taut straw* (HTS) can give us an indication on potential of lodging. It was completed by *lodging percentage* (LWF) and *lodging index* (IND).

Diseases : AB specification preventing the use of fungicides, fungal diseases were marked this last five years when conditions enabled a right distinction. From the beginning of the program, only the *rust sensitivity* could be marked (RUS).

Profitability

It appeared essential to characterise final profitability of wheat varieties for farmers. For that, *grain yield* (GY), *specific weight* (SW) and *protein content* (PRO), were measured as main variables influencing wheat growers incomes (GY being the most influencing factor). *Straw yields* (SY) was added to these last criterion to give farmers an idea of varieties ability to provide manure (when crushed on the soil) or litter (for the numerous breeders and straw sellers presents in PdL).

2. PROBLEM AND HYPOTHESIS

To help PdL farmers in their selection strategies and to foster landraces use by these farmers, CAB program implemented 3 specific sites to observe varieties in different contexts : in Laigné (53), Jarzé (49) and Bouchemaine (49), Saint-Juire-Champgillon (85). Several years of observation in these farms introducted the question : “Are wheat landraces adapted to PdL organic farming ?”.

To provide an answer, a data compilation was undertaken. It was completed by measuring agronomic criterion in 2016 fields of experiment (Jarzé, Laigné and Bouchemaine) to check if varieties implemented could be cultivated properly by PdL organic farmers.

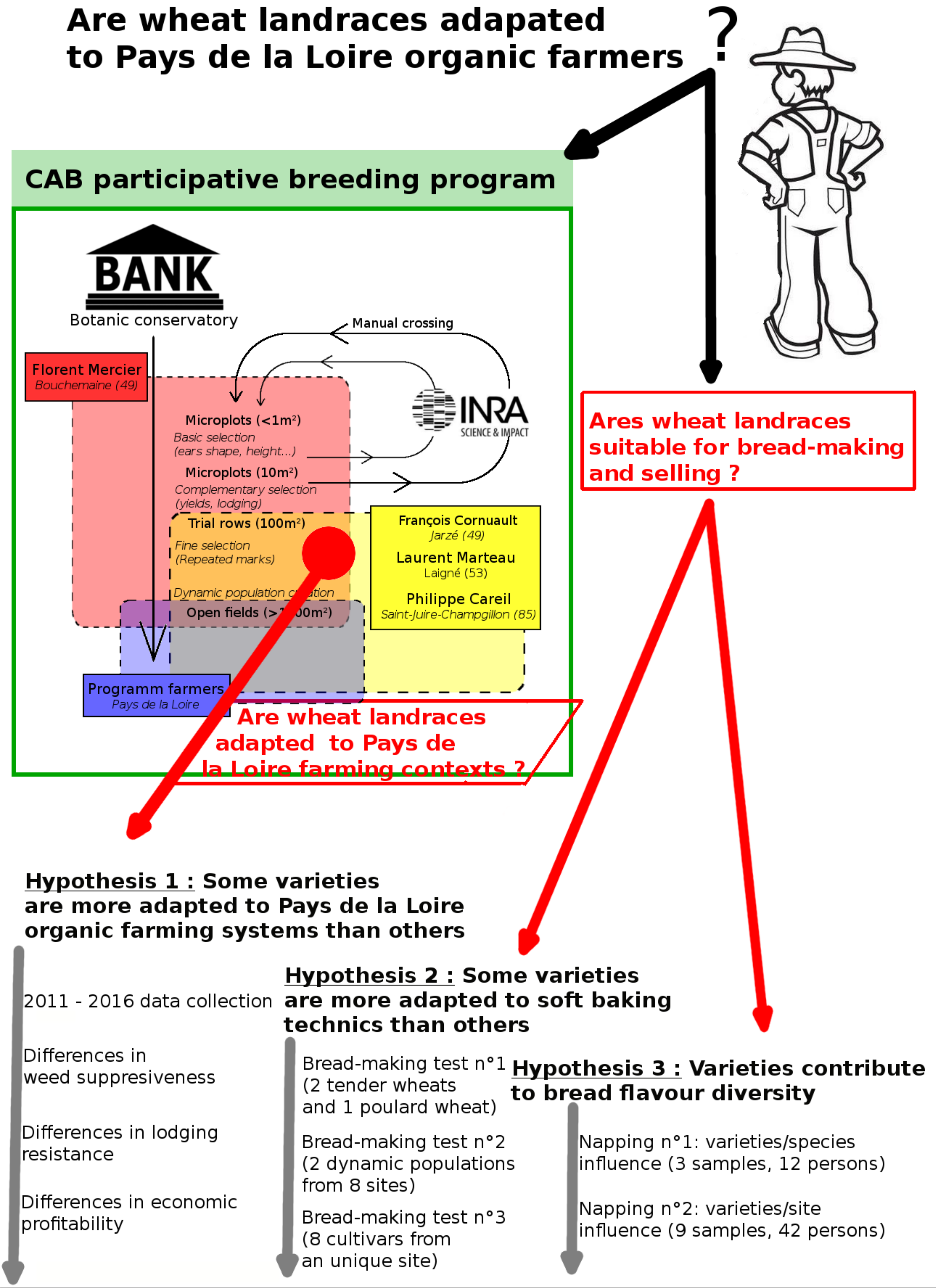
But agronomic abilities are not the only ones interesting criterion for a varieties to be spread up in farmers fields. It must be marketable, meaning that it musts present transformation properties adapted to buyers expectations. This was traduced by the implementation of a set of experiments to test baking properties and bread sensory description of varieties cultivated.

To summarise, the thesis will provide material to answer following questions:

- Are wheat landraces adapted to PdL organic farming ?
    - Are wheat landraces adapted to PdL farming contexts ?
    - Are wheat landraces suitable for bread making and selling ?

To organise this work a couple of hypothesis were formulated :

1. Within landraces, some varieties are more adapted to PdL organic farming than others.
2. Within landraces, some varieties are more adapted to soft baking techniques (slow kneading, sourdough, hand-shaping) than others.
3. Varieties contribute to bread taste diversity.


Are wheat landraces adapated
to Pays de la Loire organic farmers ?
CAB participative breeding program
BANK
Botanic conservatory
Manual crossing
Florent Mercier
Bouchemaine (49)
INRA
SCIENCE & IMPACT
Microplots (<1m²)
Basic selection
(ears shape, height...)
Microplots (10m²)
Complementary selection
(yields, lodging)
Trial rows (100m²)
Fine selection
(Repeated marks)
Dynamic population
Open fields
François Cornuault
Jarzé (49)
Laurent Marteau
Laigné (53)
Philippe Careil
Saint-Juire-Champgillon (85)
Programm farmers
Pays de la Loire
Are wheat landraces
adapted to Pays de
la Loire farming contexts ?
Ares wheat landraces
suitable for bread-making
and selling ?
Hypothesis 1 : Some varieties
are more adapted to Pays de la Loire
organic farming systems than others
2011 - 2016 data collection
Differences in
weed suppresiveness
Differences in lodging
resistance
Differences in economic
profitability
Hypothesis 2 : Some varieties
are more adapted to soft baking
technics than others
Bread-making test n°1
(2 tender wheats
and 1 poulard wheat)
Bread-making test n°2
(2 dynamic populations
from 8 sites)
Bread-making test n°3
(8 cultivars from
an unique site)
Hypothesis 3 : Varieties contribute
to bread flavour diversity
Napping n°1: varieties/species
influence (3 samples, 12 persons)
Napping n°2: varieties/site
influence (9 samples, 42 persons)

3. METHODOLOGY

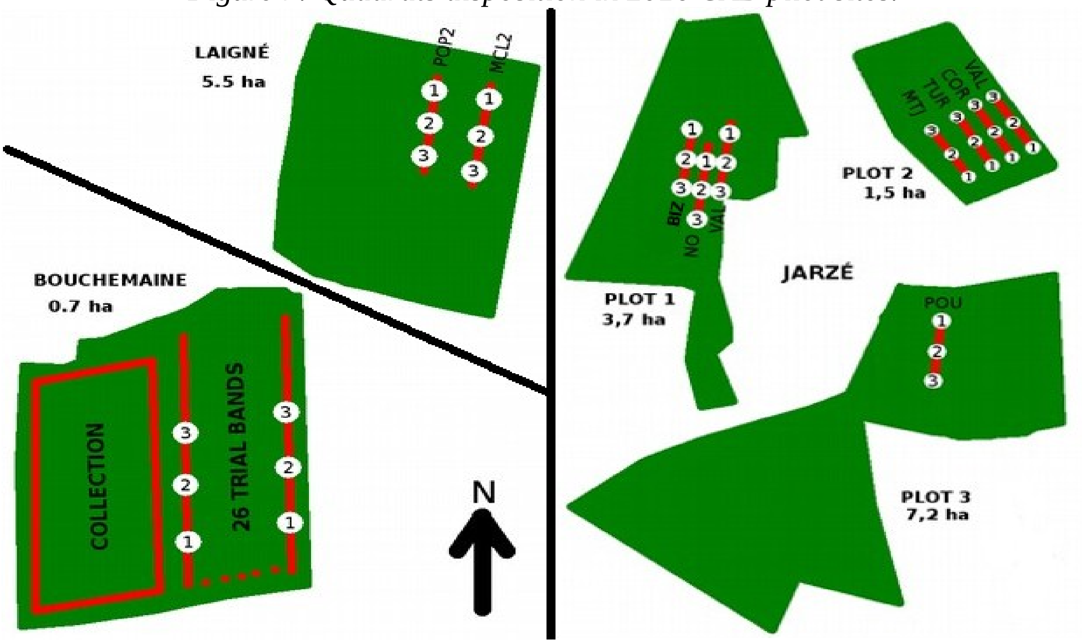
In this part will be articulated the methodology employed to test the three hypothesis mentioned earlier (that is agronomic observation, bread-making and sensory testing). We will describe design, treatments, measurements and analysis of agronomic features. Because bread-making test and sampling planing were partly similar, respective experimental design and treatments will be partially presented together.

3.1. Hypothesis 1 : landraces and agronomy

3.1.1. Experimental designed

Disposition of experiment was designed according to ITAB prescriptions (ITAB 2000) and farmers' network context. Because GABBAnjou's conditions are specific, more liberty was given to farmers while they implemented their trials to foster their participation in the research program. In fact, they sow landraces as they can (planing, surface, disposition) and GABBAnjou adapted its notations. It is then slightly different from a pilot site to another as illustrated in the case of 2016 trials on figure 7.

Figure 7: Quadrats disposition in 2016 CAB pilot sites.



In this way, 3 quadrats were sistematically set per variety cultivated and the notations were proceeded for each of them following the different dimensions listed in part 3.1.3. The 3 quadrats were located in a way to give relevant information, namely avoiding noticeable area within the plot and favouring homogeneous quadrats when possible. Table 4 shows the specificity of each plots were trials were implanted since 2011.

Table 4: Technical management of trials since 2011.

Location	**Sainte-Gemmes sur Loire**	**Bouchemaine**					**Jarzé**	
Farmer involved	Florent Mercier (FLM)	Florent Mercier (FLM)					François Cornuault (FRC)	
Soil **	Sandy	Sandy loam soil (60cm deep)	Sandy clay loam (stone =20%)	Sandy limestone	Sandy clay loam, superficial	Sandy loam soil, quite superficial, quite acid, hydromorphic, low potentials.	Sand and clay, deep soil	Carbonate clay
Year	2011	2012	2013	2014	2015	2016	2015	2016
Preceding crop	7 years grassland	4 years multispecies pastured grassland	3 years pastured grassland mowed in september	1 year grassland (clover + oat + vetch)	4 years grassland	Annual grassland (annuel clover cut + grazed)		
Fertilizing	None	None	10t/ha composted manure	None	10t/ha composted manure	10t/ha composted cowshed manure	10t/ha composted manure	
Seeding			01/12/12	28/11/13	23/11/14		31/10/14	25/10/16
Technical operations		2 inter-row hoeings Hand weeding	Thistle hand weeding	Plowing, rotary harrow, inter-row harrowing	Stubble breaking, plowing, rotary harrow	Danish cultivator, 15cm plowing, rotary harrow	Stubbles breaking, plowing, danish cultivator, post-seeding harrowing	Plowing, danish cultivator, post-seeding harrowing.

Location	Laigné						Saint Juire Champgillon (85)
Farmer involved	Laurent Marteau (LRM)						Philippe Careil
Soil **	Clay loam, deep, drained		Clay loam, very deep and drained soil (stone <15%)	Clay loam	Clay loam deep and drained soil	Clay loam	Clay and limestone, *groie* soil
	2011	2012	2013	2014	2015	2016	2013
Preceding crop	3 years multispecies grassland	Beetroots	4 years grassland	1 : wheat 2 : 4 years grassland	1 : 3 years grassland 2 : 5 years grassland	4 years multispecies grassland	Corn → Sunflower
Fertilizing	None	None	10t/ha composted manure in spring	10t/ha composted manure in spring	10t/ha composted manure	10 t of composted cow dung, on grassland in spring.	1t compost
Seeding			23/10/13	28/10/13	31/10/16	31/10/16	14/11/12
Technical operations		Strubble breaking, plowing, 2 X rotary harrow	3 X post-seeding harrowing	stubble breaking, plowing, rotary harrow, post-seeding harrowing	Superficial plowing, rotary harrow, post-seeding harrowing	3 X stubble breakings, superficial plowing, danish cultivator, sowing, harrowing right after sowing and in following spring.	Harrowing, 2 X interrow harrowing in march

3.1.2. Treatments

As reported in table 5, 42 varieties were marked in 2016. Each year, each varieties was repeated at least 3 times (once per plot, with 1 exception for “Mélange pâte” in 2014 in Laigné), enabling standard deviation calculation, what is essential for many statistic tests.

Table 5: Number of plots marked by CAB since 2011

Species	Varieties	Code	2011		2012		2013			2014		2015			2016			Total
			Laigné	Sainte-Gemmes-sur-Loire	Bouchemaine	Laigné	Bouchemaine	Laigné	Saint-Juire-Champgillon	Bouchemaine	Laigné	Bouchemaine	Jarzé	Laigné	Bouchemaine	Jarzé	Laigné	
Triticum turgidum	B198	B198		16	4	4												**24**
	Bizargari	BIZ	10	16	4	4							3			3		**40**
	Blanco de Corella	COR	10	16	4	4				4		3			3	3		**47**
	Gigante Lampino de Najera	NAJ		16	4	4												**24**
	Gigante Lampinode Najeira X Blanco de Corella	NAJ*COR													3			**3**
	Jejar de Valencia	VAL													3	6		**9**
	Mélange pâtes	POU	5		4	4			4		1		3			3		**24**
	Nonette de Lausane	NO	10	16	4	4	6					6			3	3		**52**
	Nonette de Lausanne X Blanco de Corella +Blanco de Corella X Nonette de Lausanne	NO*COR+COR*NO										3			3			**6**
	Nonette de Lausanne X Jejar de Valencia	NO*VAL													3			**3**
	Oulianowska	OUL		16	4	4												**24**
	Poulard de Chine	CHI	10	16														**26**
	Poulard de Grèce	B160		16	4	4												**24**
	Turgidum di Maliani	TUR		8	4	4				4					3	3		**26**
	Turgidum di Maliani X Nonette de Lausanne	TUR*NO													3			**3**
Triticum aestivum	Alauda	ALA	15	16	4	4	3			4		3			3			**52**
	Alauda X Rojo de Sabando	ALA*SAB										3			6			**9**
	Alauda X Soandres Laracha	ALA*SOA													3			**3**
	Attlass	ATT	5	16	4	4												**29**
	Barbu du Maconnais	MAC		16	4	4												**24**
	Bladette de Provence	BLA	10	16	4	4	6			4		3			3			**50**
	Bladette de Provence X Saint Priest et le Vernois Rouge	BLA*PRI													6			**6**
	Mélange blé tendre paysan Jarzé	MTJ														3		**3**
	Mélange de variétés commerciales de Laigné n°1	MCL1	5															**5**
	Mélange de variétés commerciales de Laigné n°2	MCL2						4		4	3	3		3	6		3	**26**
	Piréneo	PIRE			4	4												**8**
	Population dynamique n°1	POP1	10	16	3	4	6			4		3			6			**52**
	Population dynamique n°2	POP2			5	4	15	4		4	3	3		3	9		3	**53**
	Population Safari	SAF								4								**4**
	Redon roux pâle	RRP										3						**3**
	Redon roux pâle 1.13	RRP1.13								8								**8**
	Renan	REN		16	4	4	12					6			3			**45**
	Riema	RIE		16	4	4												**24**
	Rojo de Sabando	SAB	10	16	4	4												**34**
	Royo de Pamplona	ROY	10	16	4	4												**34**
	Saint Priest et le Vernois Rouge	PRI	15	15	4	4	12			4		3			3			**60**
	Saint Priest et le Vernois Rouge + Bladette de Provence + Redon roux pâle	PRI+BLA+RRP										3						**3**
	Saint Priest et le Vernois Rouge X Bladette de Provence	PRI*BLA										3						**3**
	Saint Priest et le Vernois Rouge X Rouge de Morvan	PRI*MOR													3			**3**
	Saint Priest et le Vernois Rouge X Royo de Pamplona	PRI*ROY													3			**3**
	Sixt sur Aff	SIX					6											**6**
	Soandres Laracha	SOA	10	16	4	4												**34**

3.1.3. Measurements

For notations, the ITAB guidelines were used as basis and adapted to the context of CAB farmers network (ITAB 2000).

- Weed suppressiveness
  - Winter losses (WL)

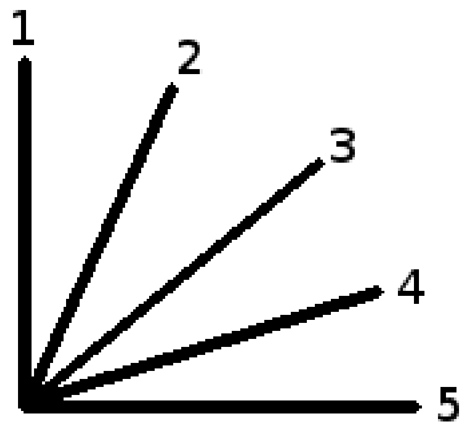
We marked winter losses by counting number of shoots per quadrat for each repetition. This mark should preferentially be carried out before tillering to facilitate counting.

- Holding (at tillering)

We marked holding (HOL) when most of the varieties reached the end of tillering period (figure 8), using figure 9 as reference.

Figure 8: Holding marking wheat stage

Figure 9: Holding marking scale



- Height (in april, may and at maturity)

Height was measured three times along wheat development cycle. Firstly in april (APR), when upright bearing was achieved, secondly in may, to give indication on wheat growth in a period when weeds are particularly competitive. We finally wrote down height when wheat achieved maturity (HTS) in order to give a last indication on weed competition. Each measure was rounded to 5cm, with the tool presented figure 10.

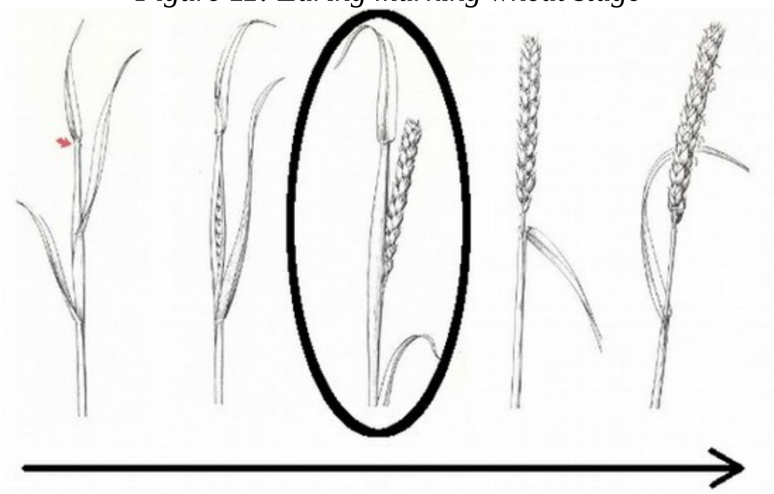
Figure 10: Wheat measurement tool used for height notation.

- Covering (COV)

Covering power often increases between tillering and 2 knots stages, and decrease from 2 knots to earing (CREAB 2009). It appears then relevant to proceed covering mark at 2 knots stage. Because this would require a lot of time to wait and observe 2 knots stage for each varieties (multiplication of travels for each site), we could not afford to proceed this way. Nevertheless, we decided to mark each varieties at the same stage. As explain further, varieties were evaluated frequently during earing periods. We took advantage of earing observations (figure 11) to mark covering when varieties presented 10 to 50% ears/quadrat.

Figure 12: Exemple of opposite holding wheat varieties categories.

Figure 11: Earing marking wheat stage



- Adaptation to the environments

PdL presents various farming contexts (pedo-climatic environments and farming practices).To foster landraces adaptations and farmers choices, varieties were marked in different farming contexts (part 3.1.1). In this way, farmers will be able to chose varieties apparently more adapted to their own farming practices and environment.

- Economic interest

To give farmers an idea of the end-products they can get through each landraces cultivations, we realised post-harvest measures. As done previously, we measured each quadrat (3 x 1m²/varieties were harvested) to get statistically usable results (possibility to calculate standard deviation).

Figure 13: Sheaf sorting (weed extraction + number of ears counting)

- Straw yield

For each harvested quadrat, we extracted weeds (figure 13), and wheat straw yields (SY) were calculated by the difference :

$$\textit{Quadrat weight}\left(\textit{weed biomass excluded}\right) - \textit{Quadrat threshed grain weight}$$

The result was finally converted into ton per hectare (t/ha).

- Grain yield (GY)

Harvested sheafs were threshed and sorted (figure 14). Resulting grain was weighted. And the result was converted into quintals per hectare(qt/ha).

Figure 14: Experimental threshing (left side) and sorting machines (right side)

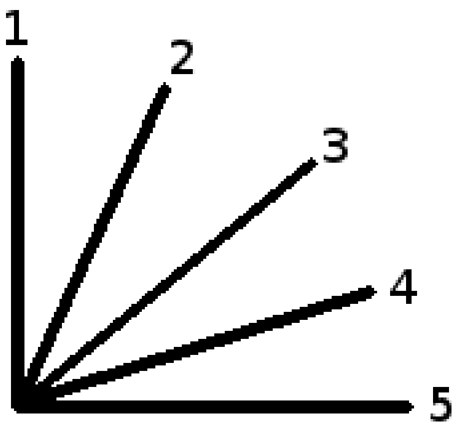
Source : Jean Lognonne's drawing during a CAB event

- Damage resistance
  - Diseases

These marks gave indication on wheat rusticity and can be proceed only when conditions are favourable to fungal diseases development.

  - Lodging

Figure 15: Lodging index (IND) marking scale.



For each quadrat were marked percentage of straws lodged (LWF) and intensity of lodging (IND; angle with soil, as described on figure 15) from 1 (straight = lodging resistant) to 5 (spread = lodging sensitive).

To make lodging statistical analysis easier, a balanced mean (Global Lodging = LOD) was calculated thank to these marks :

$$LOD = \frac{1 \times (1 - LWF) + IND \times LWF}{100}$$

3.1.4. Statistical analysis

Data structure resulting from 2011-2016 was triggering to exploit :

- Previous responsible of GABBAnjou-program did not always mark the same attributes.
- Some data were exclusively available on the form of weighted average. This prevented variance study of data collected, which is essential to proceed many statistic tests.
- The resulting data set was very unbalanced with often few varieties marked for each combination Site*Year.

For this reason, we first analysed data coming from Bouchemaine in 2016 : this seemed quite relevant since the varieties bred in Bouchemaine this year were the one selected last years for their agronomic assets. This dataset is also advantageous to analyse since each observed varieties is repeated 3 or 6 time in the same conditions, insuring direct and reliable comparability of marks.

We performed a preliminary global analyse to get an overview on the “best varieties” this year. Descriptors were grouped into categories by allocating a coefficient to each of them, according to their relative influence.
We used bibliographic work to weight WL, HOL, COV, APR and HTS within the category “weed suppressiveness”. Each mark were converted into percentage of top rated varieties for a given year. Coefficient vary according to data available (table 6).

Table 6: Weed supressivness composing descriptors coefficient

Descriptors	Coefficient
WL	1
HOL	1,5
COVm	3
HTS / APR (according to data measured)	3 / 2

Because no data was collected on diseases resistance during three years, LOD was the only descriptor available to give informations on “damage resistance” category.
Economic profitability was assessed by adding economic value of grain (450€/ton) and straw (40€/ton).

For each group, we got a global mark. These 3 marks were finally added up attributing the percentage of maximal rate for each varieties. We finally performed one-factor anovas and TukeyHSD to report group letters on barplots emphasizing significant group within dataset.

Other statistical analyses were proceeded to confirm/disconfirm 2016 results. When analysis focus on data since 2011, only varieties repeated at least three years and three times per year were taken from the general dataset. Variance were tested with two-factors anovas (years and varieties). Post-hoc tests were carried out according to anova summaries :

- When null hypothesis were accepted, we did not perform any post-hoc test
- When null hypothesis was rejected :
  - When varieties*years interactions effect was not significant, we ranked varieties on a barplot with one bar by varieties (without year differentiation). Each bar were associated to a letter / group of letters resulting from a preceding Tukey test.
  - When varieties*years interactions was significant, we ranked varieties on a barplot with one bar by varieties*years. Each bar were associated to a letter / group of letters resulting from a preceding Tukey test.

3.2. Hypothesis 2 and 3: bread-making and sampling

3.2.1. Experimental designed

As described in part 1.2.4, very few information is available regarding landraces baking quality, even if various initiatives poped up across France to increase our knowledge on this topic. As it is common for such studies, it was decided to implement field bread-making trials. When possible, we organised sampling of baked bread right after bread-making test, to explore relative influence of landraces/terroir on bread final taste. Three tests were thus realised according to opportunities and grain availabilities.

3.2.1.1. Test 1 : baking and sampling

The test 1 occurred in Erwan Gentric bakehouse (figure 16), where a formation was given by GAB44. Responsible let us the opportunity to include 3 varieties to their test (5 samples in total). All the chosen varieties came from Florent Mercier's fields (see part 3.2.2). Sourdough was hand-mixed, according to Erwan Gentric daily bread making.

A GABBAnjou course on nutritional aspect of bread let space to sample final breads (figure 18). We could proceed sampling different ways, depending on time consuming, quality and quantity of people available, costs and purpose investigated. In our case, we decided to use Napping® method. This technique involves grouping a range of product on a bi-dimensional space (like a tablecloth) following judges' own descriptive vocabulary. It leads to a link of each product to two or three adjectives describing it (Perrin et al 2008). Offering a compromise between relativity of data from identification method and time-consumption of the Quantitative Descriptive Analysis, napping® is a technique providing specific data for a substantial quantity of products. Choosing Napping® method ensured data acquisition at short term.

Figure 16: 5 experimental dough kneaded by Erwan Gentric (6th June 2016).

Figure 17: Test 2 breads in Pierre Raphaël's bakehouse (30th June 2016)

3.2.1.2. Test 2 : baking and sampling

The second test took place in Pierre Raphaël's bakehouse (figure 17). It was decided to evaluate the two mainly used dynamic population from CAB (P*opulation dynamique n°1* and P*opulation dynamique n°2*) coming from various places (see part 3.2.2). This enabled the relative influence of varieties/terroir appreciation. Bread making process was followed with endogenous sourdough for each sample.

Napping® was then realised with 42 person constituting a semi-naif panel (students, farmers, bakers, scientists attending a professional event on wheat landraces in Bouchemaine) (figure 19).

Figure 18: Test 1 breads Napping®.

Figure 19: Test 2 breads Napping®.

3.2.1.3. Test 3 : baking

The last bread-making test took place at *Maison des compagnons du devoir* in Tours on Tuesday 25th October. Experimental baker was Thibaud Ferard: working for a French mill, he carries out such tests (e.g. BIPEA test, with similar marking process) every week. Two similar kneading machines (with same volume, and time of kneading), one proofer (fermentation speed management) and an electric oven (enabling precise temperature and mist control) helped to get very similar processes between the 9 tested varieties. These last were chosen according to minimum available quantity (4kg of grain/sample), agronomic selection (observed some years within the collection), baking potential (only tender wheat varieties were tested) and comparability (all varieties were cultivated in similar conditions and harvested in 2015, in Florent Mercier's farm).

For each test, we tried to fix as many variables as possible. For test 1 and 3, we baked with precisely the same quantity of each ingredients (GAB44 decision for the formation purpose) while for test 2, we added different quantity of water to get proximate dough texture for each sample. Sourdough was obtained the day before by mixing bakers' pre-dough with each flour evaluated, in similar quantities from bakers' habits. The process followed can be consulted in annexe 2.

3.2.2. Treatments

Table 7: Bread-making tests samples description

Test	Napping code	Varieties	Origin	Milling date	Mill	Sieve	Laying time
1 – ALASAB	alauda_rojo	Alauda X Rojo de Sabando	Florent Mercier	06/06/16	Astrié 50cm, Florent Mercier	300 µm (≈T80)	3
1 – BLAPRI	bladette_st_priest	Bladette de Provence X Saint-Priest et le Vernois Rouge	Florent Mercier	06/06/16	Astrié 50cm, Florent Mercier	300 µm (≈T80)	3
1 – COR	poulard	Blanco de Corella	Florent Mercier	06/06/16	Astrié 50cm, Florent Mercier	300 µm (≈T80)	3
2 – POP1FLMC	POP1FLMC	Population Dynamique n°1	Florent Mercier (collection)	01/07/16	Astrié 50cm Pierre Raphaël	300 µm (≈T80)	1
2 – POP1JLB	POP1JLB	Population Dynamique n°1	Julien Lebihan	01/07/16	Astrié 50cm Pierre Raphaël	300 µm (≈T80)	1
2 – POP1PRF	POP1PRF	Population Dynamique n°1	Pierre Raphaël	01/07/16	Astrié 50cm Pierre Raphaël	300 µm (≈T80)	1
2 – POP1SMP	POP1SMP	Population Dynamique n°1	Samuel Poupin	01/07/16	Astrié 50cm Pierre Raphaël	300 µm (≈T80)	1
2 – POP2FLMC	POP2FLMC	Population Dynamique n°2	Florent Mercier (collection)	01/07/16	Astrié 50cm Pierre Raphaël	300 µm (≈T80)	1
2 – POP2FLM	POP2FLM	Population Dynamique n°2	Florent Mercier (plein champs)	01/07/16	Astrié 50cm Pierre Raphaël	300 µm (≈T80)	1
2 – POP2JPJ	POP2JPJ	Population Dynamique n°2	Jean-Paul Jolivel	01/07/16	Astrié 50cm Pierre Raphaël	300 µm (≈T80)	1
2 – POP2JLC	POP2JLC	Population Dynamique n°2	Julien Cesbron	01/07/16	Astrié 50cm Pierre Raphaël	300 µm (≈T80)	1
2 – POP2LMR	POP2LMR	Population Dynamique n°2	Laurent Marteau	01/07/16	Astrié 50cm Pierre Raphaël	300 µm (≈T80)	1
3 – HEN	[redacted]	Hendrix	Florent Mercier	23/08/16	Astrié 50cm Florent Mercier	300 µm (≈T80)	2
3 – REN	[redacted]	Renan	Florent Mercier	23/08/16	Astrié 50cm Florent Mercier	300 µm (≈T80)	2
3 – PRI	[redacted]	Saint Priest et le Vernois Rouge	Florent Mercier	23/08/16	Astrié 50cm Florent Mercier	300 µm (≈T80)	2
3 – BLAPRI	[redacted]	Bladette de Provence X Saint Priest et le Vernois Rouge	Florent Mercier	23/08/16	Astrié 50cm Florent Mercier	300 µm (≈T80)	2
3 – ALASAB	[redacted]	Alauda X Rojo de Sabando	Florent Mercier	23/08/16	Astrié 50cm Florent Mercier	300 µm (≈T80)	2
3 – POP1	[redacted]	Population dynamique n°1	Florent Mercier	23/08/16	Astrié 50cm Florent Mercier	300 µm (≈T80)	2
3 – POP2	[redacted]	Population dynamqieu n°2	Florent Mercier	23/08/16	Astrié 50cm Florent Mercier	300 µm (≈T80)	2
3 – SOAINV	[redacted]	Soandres Laracha X Involcable	Florent Mercier	23/08/16	Astrié 50cm Florent Mercier	300 µm (≈T80)	2

To test baking quality of each varieties (table 7), we milled the grain on Astrié farmers' granite millstone (figure 20) according to farmers' planing. Test 1 flour quality may differ from test 3 because Florent Mercier's millstone was trued at the end of July 2016.

During the first test, only 2 tender wheat landraces (*Bladette de Provence X Saint Priest et le Vernois Rouge* and *Alauda X Rojo de Sabando*) cultivated in Bouchemaine and milled by Florent Mercier (300 µm, Astrié mill) were tested. Added to these was tested one poulard wheat landrace (*Blanco de Corella*).

Two other varieties were tested in test 2 (*Population dynamique n°1* and *Population dynamique n°2*). In this case, we also tested influence of terroir, baking 4 samples from *Population dynamique n°1* and 5 samples of *Population dynamique n°2*.

Test 3 enabled characterisation of 8 landraces including 2 landraces tested in test 1 (*Alauda X Rojo de Sabando* and *Bladette de Provence X Saint Priest et le Vernois Rouge*) and the two populations tested in test 2 (*Population dynamique n°1* and *Population dynamique n°2*). According to stock availability and test time consuming, we tested at the same time one old "pure line" varieties[4](*Saint Priest et le Vernois Rouge*), two commercial modern pure line references (*Renan* for BAF wheat and *Hendrix* for BPS wheat[5]) and one other crossing from CAB program (*Soandres Laracha X Involcable*).

Figure 20: Astrié mill centrifugal reel (left) and millstone (right).

3.2.3. Bread-making tests specifics

3.2.3.1. Measurements

A protocol was set by a group of INRA researchers and practitioners during the study PaysBlé (Serpolley-Besson 2010). This project aimed to experiment, maintain and promote cultivated genetic diversity of Breton landraces in organic farming. For this purpose, marking descriptors was defined (Roussel and al. 2014) and the protocol was created according to AFNOR norm NF V 03-716 scale of notation (Table 8, Roussel et al. 2010), using specific descriptors for each step of bread-making process (Table 9).

4 As explained in part 1.2.3, it is no way possible to certify genetic homogeneity of landraces since they are not registered in FOC. We use the term « pure line » here, to speak about the resulting population from botanic conservatory multiplication.

5 BAF (Blé Améliorant ou de Force) and BPS (Blé Panifiable Supérieur) are french acronymes to qualify respectively top baking quality and good baking quality tender wheat. It is used to give information on tender wheat varieties in the FOC.

Table 8: NF V 03-716 AFNOR notation scale norm

DEFICIENCY (-)				EXCESS (+)		
1	4	7	10	7	4	1
Fault intensity						
Very pronounced	Pronounced	Quite pronounced	Normal	Quite pronounced	Pronounced	Very Pronounced

Table 9: PaysBlé descriptors transcription.

Bread-making step	**French descriptor**	**Descriptor traduction**
Kneading	Fermeté Collant Tenue Extensibilité Lissage Résistance élastique	Firmness Stickiness Holding Extensibility Smoothing Elastic resistance
Fermentation	Pousse Suintement Tonicité	Growth Seepage Tonicity
Shaping	Collant Allongement Déchirement Tonicité	Stickiness Lengthen Tearing Tonicity
Proofing	Cloquage Porosité Tenue Pousse	Blistering Porosity Holding Growth
Loading	Collant Tenue Expansion au four	Stickiness Holding Expansion
Bread outside aspect	Développement Section Brunissement Brillance Épaisseur de la croûte Écaillage de la croûte Croustillant Développement de la grigne	Growth Section Tanning Brilliance Crust thickness Crust flaking Crustiness Scars development
Bread inside aspect	Couleur Régularité des alvéoles	Colour Alveolus regularity

Even if descriptors were the same between each test, they were sometimes not evaluated, as described by table 10.

Table 10: Missing baking test descriptors.

Test	Missing descriptors	Reason
Test 1	Fermentation2.growth Fermentation2.seepage Fermentation2.holding Fermentation2.tonicity_elasticity Fermentation2.tonicity_holding Fermentation2.stickiness	Only one fold performed by the baker
	Bread.tanning, Bread.brilliance, Bread.crust_thickness, Bread.crust_hardness, Bread.crust_flaking, Bread.crustiness, Bread.scars_development, Inside.brilliance, Inside.supplness, Inside.elasticity, Inside.stickiness, Inside.alveolus_regularity, Inside.alveolus_wall_thickness	Lack of time
	Proofing.growth, Loading.stickiness	Mistake
Test 2	Fermentation1.tonicity_elasticity, Fermentation1.tonicity_holding, Fermentation1.stickiness, Fermentation2.growth, Fermentation2.seepage, Fermentation2.holding, Fermentation2.tonicity_elasticity, Fermentation2.tonicity_holding, Fermentation2.stickiness	No fold performed by the baker
Test 3	Loading.expansion, Bread.section	Confusion with bread developpement
	Inside.supplness	Confusion with elasticity

For scientific appropriation of collected data, we specified for each test (as much as possible) : the name and the origin of the varieties of wheat, test date, mill used, floor laying time, baker, room temperature, mass of each ingredient, as well as sensory appreciation of sourdough, kneading, proofing, pushing and baking duration, type of kneading, number of folds, dough temperature (after kneading), and baking temperature.

3.2.3.2. Statistical analysis

Because bread-making tests are carried out by bakers having sensory references regarding to dough/bread texture and aspect, there is no need of numerous repetitions for each varieties tested to get relevant results. That's why we use directly rough data to compare these tests. To provide some specific information (varieties or terroir comparison), we sometimes sum up marks from related tests, but no statistical test was perform to assess these hypothesis.

Because some marks were missing (table 10, part 3.2.3), we compare baking process steps according to percentage of maximum rate obtained for each step.

<u>Example :</u> *If one varieties got 10/10, 7/10 and 4/10 marks related to « shaping » step : corresponding mark will be « 0,70 » (= 70%) instead of « 21/30 » (enabling comparison with others varieties marked « X/40 » or « X/50 »).*

Because test 1 excluded inside bread rating, inside and outside bread marks were gathered into « Bread » rating group (weighted mean) for final comparison (graph 10, part 4.2).

3.2.4. Napping® specifics

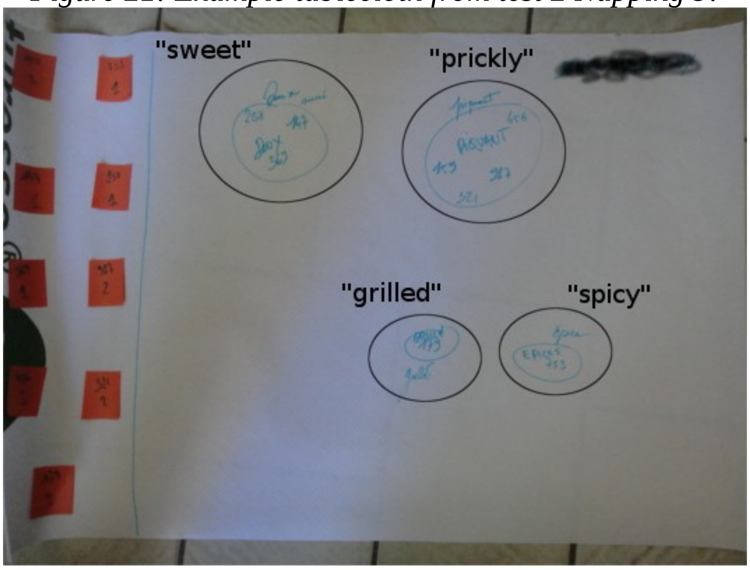
3.2.4.1. Measurements

Napping® measurement can be divided into two main parts :

The sorting task : each taster is asked to position the whole set of products on a sheet of blank paper (a tablecloth) according to their similarities/dissimilarities. Namely, two products are closed if perceived as similar or, on the contrary, are far-off one another if perceived as different. Each taster uses his/her own criteria.

The verbalisation task : After performing the napping® task, the panellist are asked to describe the products by writing one or two sensory descriptors characterizing each group of products on the map (figure 21).

Figure 21: Example tablecloth from test 2 Napping®.



3.2.4.2. Statistical analysis

Napping® data leads to a quantitative table. The rows represent bread sampled. Two columns are set for each panelist corresponding to X-coordinate and Y-coordinate for each product[6]. Sensory descriptors are coded through a products*words frequency table (figure 11). First a contingency table counting the number for which each descriptor has been used to describe each product is created. Then the contingency table is transformed into frequency table so that “word frequency” is a qualitative variable with the number of words cited as modalities.

6 X and Y coordinates are calculate on Engauge-Digitizer software

Table 11: Test 2 Napping® frequency table structure.

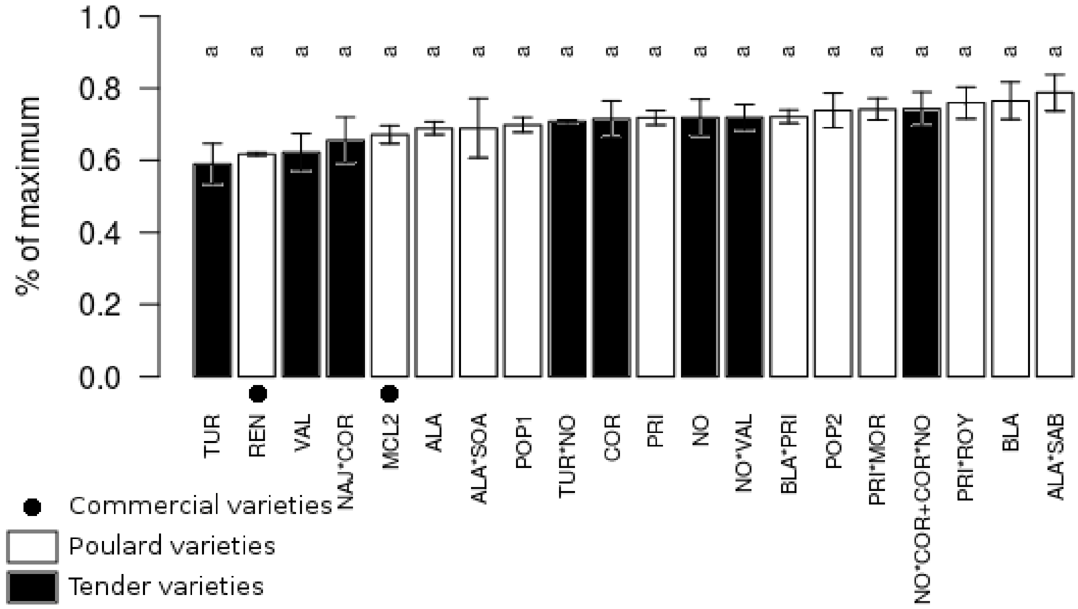
name	product	X1	Y1	…	X43	Y43	acid	sweet	flour	fruity	honey
POP2JLC	159	21.457	26.4167	….	35.0921	10.6574	7	3	4	2	2
POP1JLB	753	15.2048	13.3812	….	9.37739	33.5509	6	1	3	4	4
POP1PRF	147	33.4034	8.40466	….	26.1455	36.2111	4	5	3	4	1
POP1FLM-C	258	28.2551	8.34644	….	29.2356	13.7008	9	7	2		
POP1SMP	369	15.2745	10.8916	….	14.2371	3.57336	5	3	4	6	3
POP2JPJ	987	22.7356	18.8802	….	33.2308	35.7687	4	6	1	2	1
POP2FLM-C	456	21.1741	21.5924	….	34.2738	13.8491	7	7	3	3	3
POP2LRM	321	22.2014	30.3344	….	38.7181	13.4928	4	5	2	3	5
POP2FLM	179	16.3665	8.10026	….	24.1366	3.61667	9	4		3	3
							55	41	22	27	22

To analyse the kind of data, a Multiple Factor Analysis (MFA) was performed. Each subject constitute a group of two un-standardised variables. The MFA led to a synthesis of the panellist's tablecloth. Two products are closed if all judges consider them close on the napping®. The more the two first components of MFA explain the original variability, the more the judges are in agreements. The frequency table crossing products and word frequency is considered as a set of supplementary variable : they do not intervene in the axes construction but their correlation with the factors of MFA are calculated and represented as in usual Principal Component Analysis (PCA).

4. RESULTS

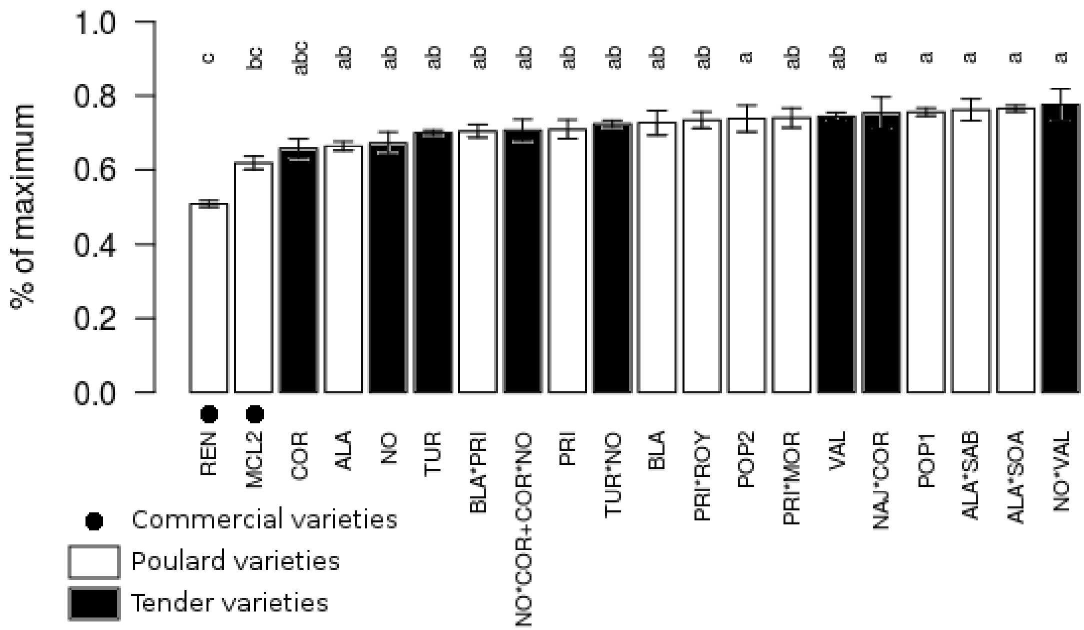
4.1. Agronomy

Graph 4: Global Tukey class-ranking (Bouchemaine, 2016)



Between all varieties compared together in 2016, there is no significant difference when all descriptors are gathered (graph 4). We can assume that gathering effect may smooth results since varieties may for example be well rated for weed competition and low rated for economic interest (what is respectively described on graph 5 and graph 9). On this same graph, there is no apparent difference between poulard wheat (black columns) and tender wheat (white columns).

Graph 5: Weed supressiveness Tukey class-ranking (Bouchemaine, 2016)



Graph 6: Weed suppressiveness Tukey class-ranking (Bouchemaine - 2013+(2014-2015)+2016)

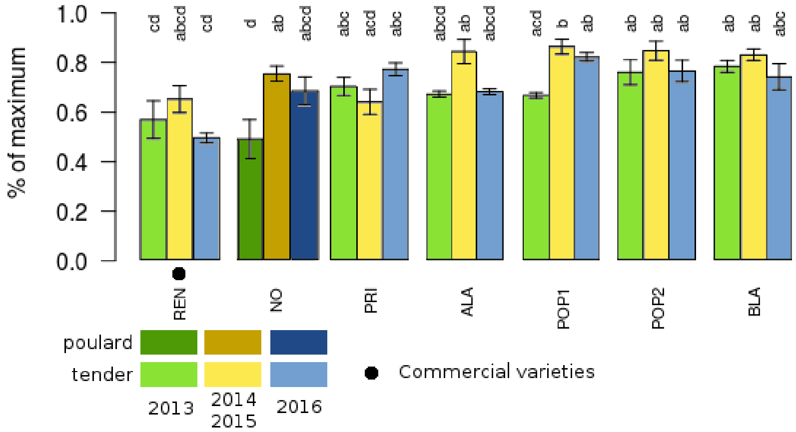
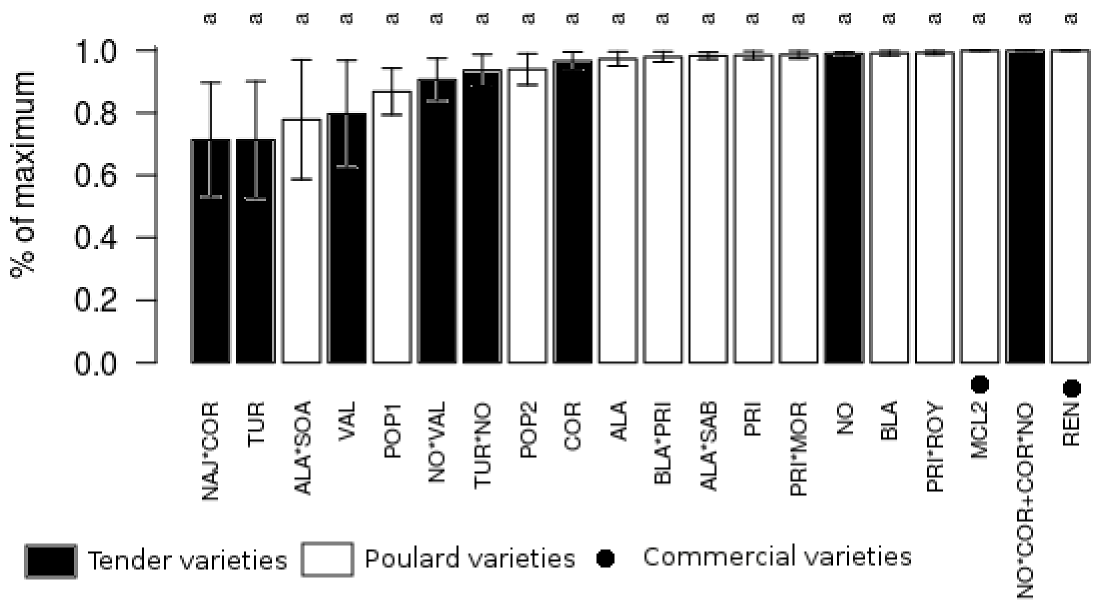


Table 12: Weed suppressiveness 2 factors Anova (Bouchemaine 2013+(2014-2015)+2016)

```
                  Df Sum Sq Mean Sq F value   Pr(>F)
Brut$YEA           2 0.3572 0.17860  20.357 3.73e-08 ***
Brut$VAR           6 0.6853 0.11422  13.018 7.37e-11 ***
Brut$YEA:Brut$VAR 12 0.2965 0.02471   2.816  0.00231 **
Residuals        101 0.8861 0.00877
```

This hypothesis seems confirmed by Graph 5 showing that the two commercial varieties (REN and MCL2) are significantly less competitive against weeds than landraces POP2, POP1, ALA*SAB, ALA*SOA and NO*VAL. Since years 2014 and 2015 were not significantly different (p-value = 0,07), they were gathered into a single category (table 12 and graph 6) to maximize the number of compared varieties. Because VAR*YEA interaction effect is significant (table 12), each year is specified by a dedicated bar on graph 6. It shows that there is no varieties significantly different from another every inspected year. However, REN (commercial varieties control) is several years significantly inferior to POP1 (2016), POP2 (2013+2016) and BLA (2013). It is the case for NO (poulard) compared to PRI (2013), POP2 (2013) and BLA (2013) and PRI compared to POP1(2014+2015).

Graph 7: Lodging resistance Tukey class-ranking (Bouchemaine – 2016)



Graph 8 : Lodging sensitivity Tukey class-ranking (Bouchemaine-2012+2013+2016)

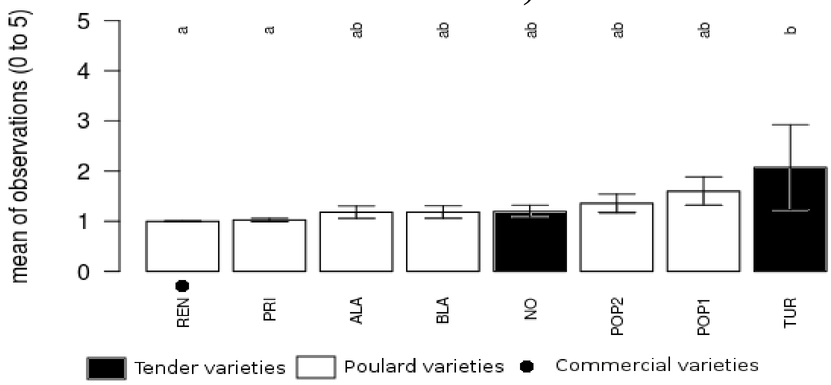


Table 13: Lodging 2 factors Anova summary (Bouchemaine 2012+2013+2016)

	Df	Sum Sq	Mean Sq	F value	Pr(>F)	
Brut$YEA	1	0.224	0.2237	0.805	0.3748	
Brut$VAR	7	4.448	0.6354	2.288	0.0465	*
Brut$YEA:Brut$VAR	7	1.754	0.2506	0.903	0.5141	
Residuals	40	11.107	0.2777			

Graph 7 does not show any difference between varieties, even if NAJ*COR, TUR, ALA*SOA, and VAL seem visually very different from the others varieties. This can be explained by high standard deviances for these 4 cultivars. Considering repeated data since 2012 (graph 8 and table 13), we can certify that REN and PRI are more resistant to lodging than TUR. No effect from year can be pointed out for this descriptor.

Graph 9: Economic value Tukey class-ranking (Bouchemaine - 2016)

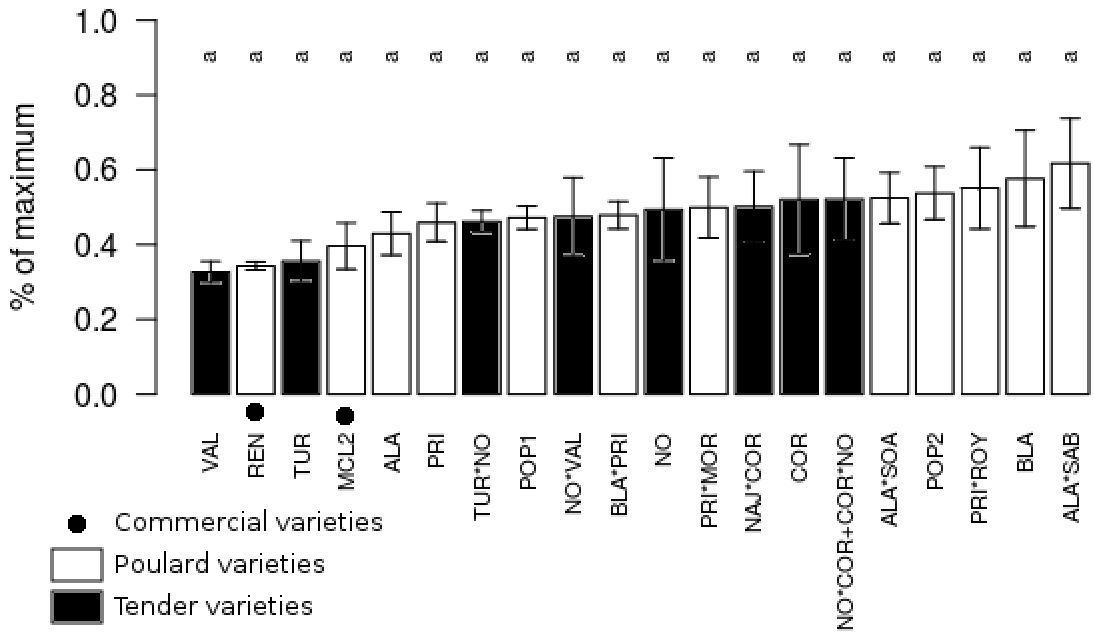


Table 14: Economic value 2 factors Anova (Bouchemaine – 2013+2014+2015+2016)

	Df	Sum Sq	Mean Sq	F value	Pr(>F)	
Brut$YEA	2	13639161	6819580	108.643	<2e-16	***
Brut$VAR	6	732074	122012	1.944	0.0841	.
Brut$YEA:Brut$VAR	12	2010309	167526	2.669	0.0047	**
Residuals	78	4896103	62771			

Graph 9 does not shows any significant difference between varieties according to economic profitability. However, we can assume visually that poulard wheats VAL and TUR and commercial varieties REN and MCL2 are different from some others landraces such as BLA and ALA*SAB that seem quite productive in 2016. No difference can neither be significantly proofed with 4 years data gathering (table 14).

*Table 15: Grain yield Tukey site*Varieties interaction effect (Laigné + Bouchemaine, 2013+2014+2016)*

	diff	lwr	upr	p adj
POP2-MCL2	1.652245	-3.135615	6.440105	0.4915791

$`Brut$SIT:Brut$VAR`

	diff	lwr	upr	p adj
Laigné:MCL2-Bouchemaine:MCL2	17.030	6.92475044	27.1352496	0.0002451
Bouchemaine:POP2-Bouchemaine:MCL2	7.732	-0.72265837	16.1866584	0.0843730
Laigné:POP2-Bouchemaine:MCL2	10.190	0.08475044	20.2952496	0.0473965
Bouchemaine:POP2-Laigné:MCL2	-9.298	-17.75265837	-0.8433416	0.0258647
Laigné:POP2-Laigné:MCL2	-6.840	-16.94524956	3.2652496	0.2862977
Laigné:POP2-Bouchemaine:POP2	2.458	-5.99665837	10.9126584	0.8666579

Table 15 shows that MCL2 grain yield is significantly superior when cultivated in Laigné, but POP2 is neither significantly inferior nor superior when compared between Laigné and Bouchemaine.

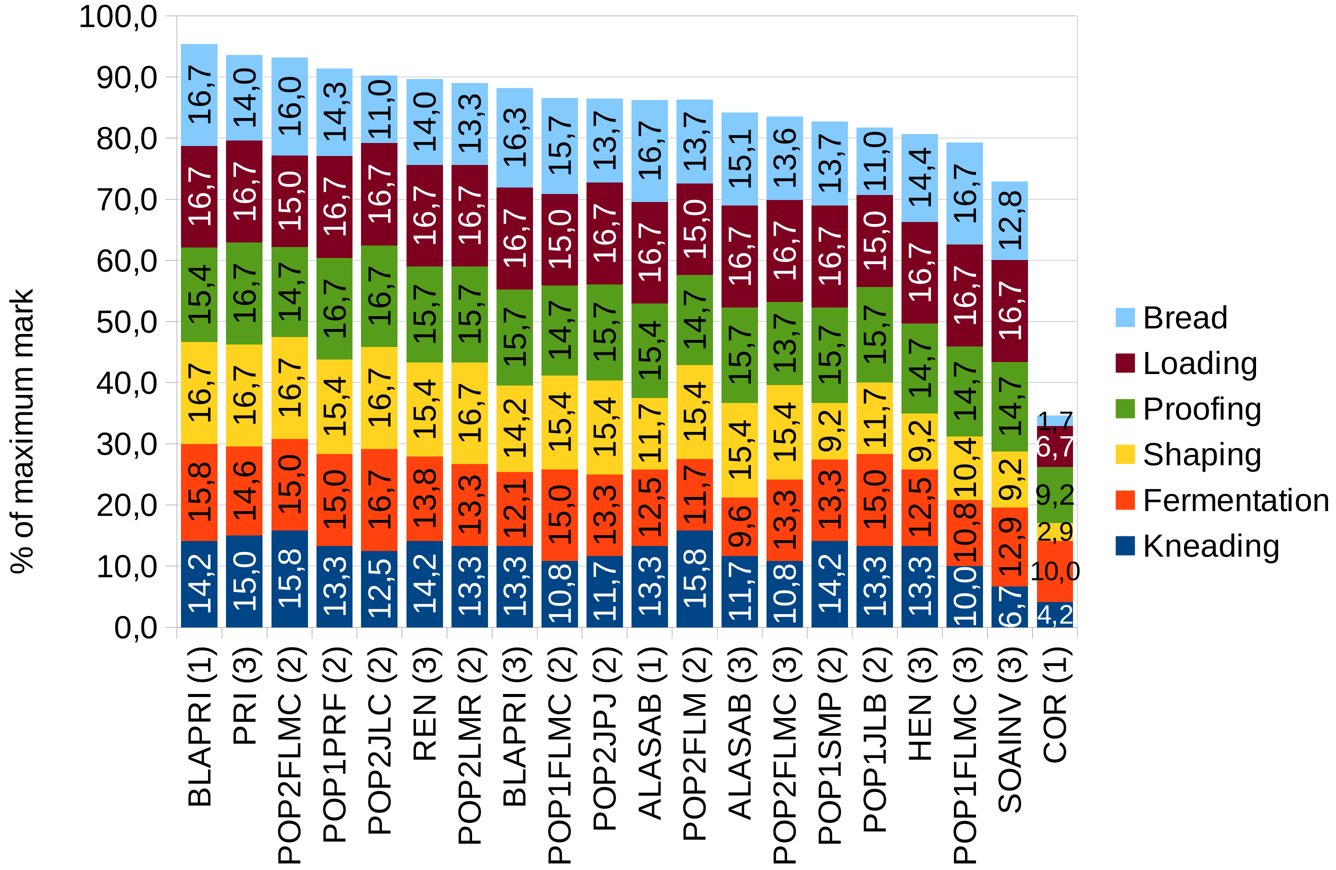
*Table 16: Site*Varieties 2 factors Anova (Bouchemaine + Jarzé, 2016, COR+NO+TUR+VAL)*

	Df	Sum Sq	Mean Sq	F value	Pr(>F)	
Brut$SIT	1	65.6	65.59	3.094	0.0947	.
Brut$VAR	3	81.8	27.26	1.286	0.3078	
Brut$SIT:Brut$VAR	3	18.3	6.09	0.287	0.8341	
Residuals	19	402.7	21.20			

Table 16 Anova shows no significant different between any varieties or site.

4.2. Baking quality

Graph 10: Baking test results.



Graph 10 shows results of each test with marked gathered by baking step. Step maximum mark is 16,7 %, leading global maximum mark to *6 (number of steps) x 16,7 %* = 100 %. Samples are ranked between 73,0 % (*Soandres Laracha X Involcable*) and 95,4 % (*Bladette de Provence X Saint Priest et le Vernois Rouge*) of maximum rating.

COR (varieties *Blanco de Corella*, as referenced in table 7, part 3.2.2) being the control for poulard wheats, justifies the superiority of tender wheat to bake bread.

The two commercial varieties *Hendrix* (HEN) and *Renan* (REN) are respectively located in 6th rank (89,6%) and 17th rank (80,7%).

Table 17: Rating step basic descriptive statistic indicators

Rating step	Variance	Mean
Shaping	13,73	13,48
Bread	10,82	13,71
Kneading	8,28	12,38
Loading	5,12	15,83
Fermentation	3,55	13,31
Proofing	2,54	15,07

Table 17 shows that shaping, bread aspect (inside and outside) and kneading are the steps that explain the most of the difference between tested varieties, with respective variances of 13,73 ; 10,82 and 8,28. Namely, the varieties that induced more difficulty or dissatisfaction to bakers presented bad shaping, bread aspect and/or kneading features. Within these steps, we can emphasize 11 descriptors (among the 25) that discriminate the most varieties.

Table 18: Discriminating power of kneading, shaping and bread descriptors

Descriptors	Variance	Descriptors	Variance
Kneading.extensibility	10,33	Kneading.stickiness	5,94
Bread.section	10,00	Bread.scars_development	5,56
Kneading.elastic resistance	9,38	Shaping.tearing	5,19
Kneading.smoothing	8,79	Inside.supplness	4,75
Bread.growth	8,79	Inside.stickiness	4,37
Inside.alveolus_regularity	8,47	Inside.elasticity	3,44
Kneading.firmess	8,03	Inside.alveolus_wall_thickness	2,38
Shaping.tonicity	7,96	Bread.tanning	1,99
Kneading.holding	7,67	Bread.crust_hardness	1,72
Shaping.lengthen	7,67	Inside.brilliance	1,72
Shaping.stickiness	7,67	Bread.brilliance	1,72
		Bread.crust_thickness	1,39
		Bread.crust_flaking	1,39
		Bread.crustiness	0,53

Considering these descriptors, and gathering varieties tested by different bakers (1-BLAPRI with 3-BLAPRI, 1-ALASAB with 3-ALASAB, 2-POP2FLMC with 3-POP2FLMC and 2-POP1FLMC with 3-POP1FLMC), we obtain the final table 19.

Table 19: Varieties bread-making final ranking.

Steps	Kneading	Kneading	Kneading	Bread	Bread	Kneading	Shaping	Kneading	Shaping	Shaping	Kneading	% of maximal mark
Descriptors	Extensibility	Elastic resistance	Smoothing	Growth	Alveolus regularity	Firmness	Tonicity	Holding	Lengthen	Stickiness	Stickiness	
3 – PRI	10	7	10	10	7	10	10	7	10	10	10	92%
2 – POP2FLM	10	10	10	7	7	10	7	10	10	10	7	89%
1+3 – BLAPRI	8,5	8,5	8,5	8,5	10	7	8,5	8,5	8,5	10	8,5	86%
2 – POP1PRF	7	7	7	7	7	10	10	10	10	10	7	84%
2 – POP2LMR	7	10	4	7	7	10	10	10	10	10	7	84%
3 – REN	10	4	10	10	1	7	7	10	10	10	10	81%
2 – POP2JLC	7	4	10	4	7	7	10	10	10	10	7	78%
1+3 – ALASAB	8,5	8,5	8,5	8,5	7	5,5	10	5,5	7	7	8,5	77%
2 – POP2JPJ	7	7	1	10	4	10	10	10	10	7	7	75%
2 – POP1SMP	7	7	7	7	7	10	7	10	7	4	10	75%
2+3 – POP1FLMC	2,5	10	7	10	8,5	5,5	8,5	5,5	7	7	7	71%
2 – POP1JLB	10	10	7	1	7	7	7	10	7	7	4	70%
2+3 – POP2FLMC	8,2	7,4	7,1	7	6,4	6,8	7,2	7	7,2	6,5	6,1	70%
3 – HEN	10	4	7	10	1	7	1	10	4	10	10	67%
3 – SOAINV	1	1	10	4	7	4	10	7	4	4	1	48%
1 – COR	1	1	1	1		4	1	1	1	1	7	19%
Mean	7,2	6,6	7,2	7,0	6,3	7,5	7,8	8,2	7,7	7,7	7,3	

Table 20: POP1 and POP2 comparison within test 2.

Varieties	POP1		POP2		Global	
	Mean	Standard deviance	Mean	Standard deviance	Mean	Standard deviance
Kneading	0,78	0,09	0,83	0,12	0,81	0,10
Fermentation	0,88	0,05	0,84	0,11	0,86	0,09
Shaping	0,78	0,18	0,97	0,04	0,88	0,16
Proofing	0,94	0,05	0,93	0,05	0,93	0,05
Loading	0,95	0,06	0,96	0,05	0,96	0,05
Bread	0,84	0,19	0,87	0,16	0,86	0,16
Inside	0,79	0,06	0,72	0,14	0,75	0,11
Global	0,85	0,06	0,89	0,04	0,87	0,05

Shaping and bread aspect (outside and inside) are the most different steps between POP1 and POP2 observations. Within these steps, breads outside and inside aspects are quite similar (variance may be explained by « site effect ») while respective shaping quality of POP1 and POP2 seem different (78 % and 97 % of maximum rate). Because the number of individuals is less than 30 for each group, it is impossible to use Student test to assess statistical significance of this difference. In the case of shaping, we cannott use Wilcoxon test because there are some ex-aequos values within samples.

4.3. Sensory evaluation

4.3.1. Napping® 1

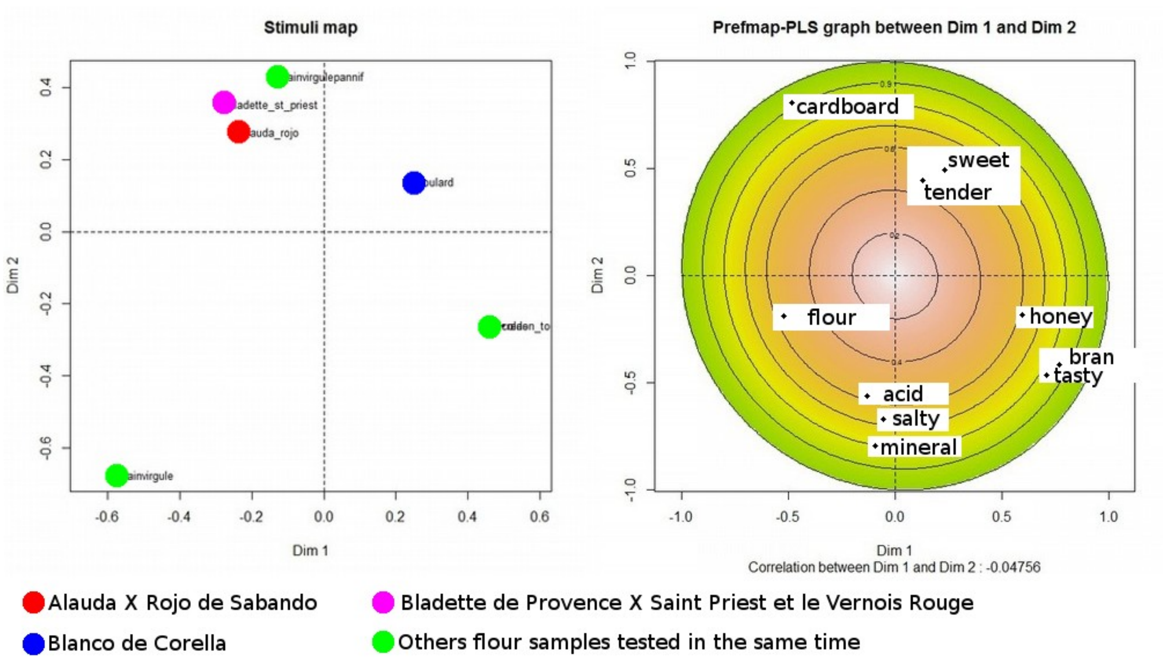
18 words were used to describe the 7 breads. Only words that were used more than twice were integrated to the test so that 10 words were used for final analysis. The words *Spicy* and *Flower* were gathered with *Honey*. The words *White flour*, *White bread* and *Baguette* were gathered as *Flour*. The words *Rye* and *Bran* were gathered as *Bran* according to *Lexique sensoriel des pains à croûte* (LEMPA and Lessafre 2015).

Overlapping the two following maps, breads proximity with a descriptor means that this specific bread was mostly associated to this descriptor. Graph 11 stimuli map first dimension is an aroma gradient from *Cardboard* and *Flour* on the left to *Tasty*, *Honey* and *Bran* on the right.

Bread *Blanco de Corella* is associated with honey and rye aromas. This may be a distinctive feature of poulard wheat breads.

The second dimension is a flavour axis going from *Salty* at the bottom to *Sugary* at the top. We observe that panellists marked BLAPRI and ALASAB quite the same way. As described on table 7, *Alauda X Rojo de Sabando* and *Bladette de Provence X Saint Priest et le Vernois Rouge* breads came from tender wheat from Florent Mercier's farm, baked the same way by Erwan Gentric.

Graph 11: Napping® 1 results

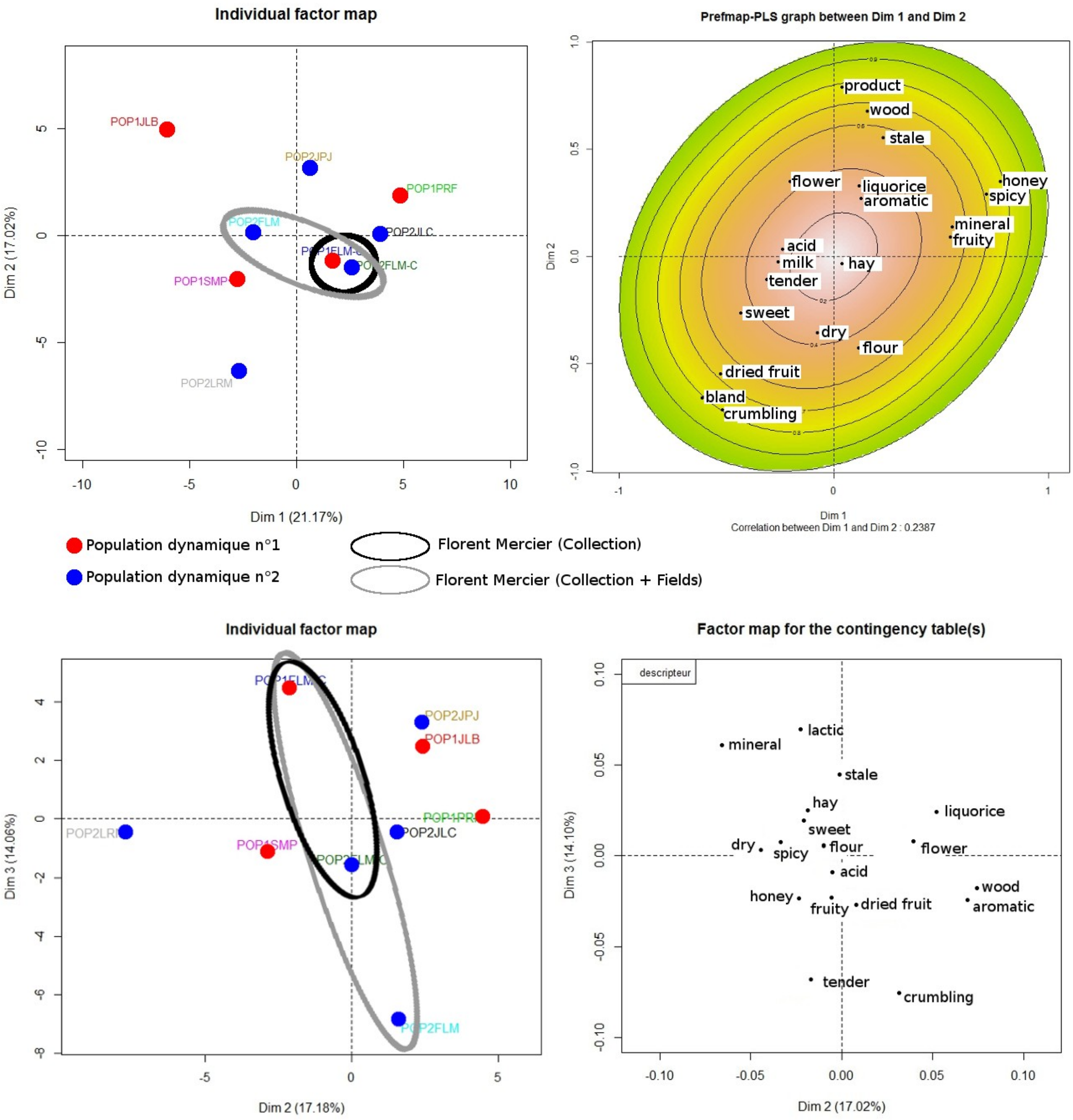


4.3.2. Napping® 2

In this description, we will let aside bread aspect or texture descriptors since they were marked through bread-making tests (part 4.2).

The two dimensions presented by Principal Component Analysis (PCA) of Napping®2 brings 38 % of whole dataset information with 21 % reported by the first dimension (Dim1) and 17 % by the second one (Dim2), what is satisfactory in the case of a large panel of 42 persons among which it is usually difficult to find consensus. The third dimension (Dim 3) represents 14% of data information.

Graph 12: Napping® 2 results



Dim1 of graph 12 brings POP1PRF + POP2JLC and POP1SMP + POP2LRM into opposition. The taste of first ones is described by honey and spice flavour while the second ones are associated with bland and dried fruits (almonds, nuts). Dim 2 brings breads with nuts aromas (POP2LRM) to others associated with wood or stale aromas (POP2JPJ).So far, individual factor map does not make out any difference POP1 and POP2. Bread resulting from Florent Mercier's wheat (grey circle on graph 12) and especially samples cultivated in exactly the same conditions (POP1FLMC and POP2FLMC; black circle on graph 12) are the furthest according to these main differentiating dimensions. These same varieties are nevertheless very different on the third dimension, which is partially constructed by texture words (POP2FLMC is described as lactic while POP2FLM as tender and crumbling).

5. DISCUSSION

5.1. About results

5.1.1. Agronomy

In general, difference between varieties is not obvious since very few significant results are statistically asserted. However, some observations can be presented :

- Commercial varieties (*Renan* and *Mélange commercial de Laigné n°2)* are mainly ranked less competitive to weeds (> 95 % confidence in various cases, as detailed in part 4.1 comments on graphs 5 and 6), more resistant to lodging (< 95 % confidence) and less productive than landraces (< 95 % confidence). Higher straws of landraces can at least partially explain weeds supressivness, lodging sensitivity and higher yield (more straw). In the case of Bouchemaine in 2016, weeds competition can explain lower yields of commercial varieties.
- Populations dynamique n°1 and n°2 do not present any significant difference neither for weeds suppressiveness and lodging, nor for economic value. We cannot point out any difference between population varieties and “pureline landraces”.
- No crossing effect can be observed in 2016. As it was the first time crossing were methodically observed, we do not have any aggregated information for several years so far.
- Poulard agronomic performances do not differ from tender wheat statistically. However, we can assume that poulard wheat are globally more sensitive to lodging. Indeed, even if no difference can be certified (except VAL-REN and VAL-PRI for 3 years), it seems that poulards are almost all ranked lower than tender wheats. NO, NO*COR+COR*NO (for poulard wheat), ALA*SOA and POP1 (for tender wheats), may be exceptions to this assumption. TUR (poulard wheat) is the only varieties significantly more sensitive to lodging from REN (tender wheat commercial varieties) and PRI (tender wheat landrace) (mean on 3 years).
- No site effect can be pointed out between Jarzé and Bouchemaine varieties in 2016. However, some relevant interactions are observables between Bouchemaine and Laigné observations in 2013, 2014 and 2016 (table 15). Laigné soil (mainly clay loam, deep and drained) being more productive than Bouchemaine (mainly sandy loam, hydromorphic, acid

and superficial), MCL2 present significantly superior grain yields in Laigné. It is interesting to note that this is not the case of POP2 for which grain yields are not significantly different in both sites. Interaction POP2*Bouchemaine is also significantly inferior than MCL2*Laigné. All these results seem to demonstrate that MCL2 is better adapted to productive soil (>99% confidence) whereas POP2 is more adapted to poor soil such as Bouchemaine (>90% confidence). This may be explained by POP2 / MCL2 height of straw, since POP2 is higher than MCL2, its cultivation in rich soils leads it to fall while its cultivation in poor soil enable better competition against weeds. We can also assume that dynamic population performances are more stable in comparison with marketed cultivars, as it is demonstrated in a recent study (Goldringer et al 2012).

5.1.2. Bread-making

What becomes evident analysing this result is the globally good baking quality of every samples. : Except in the case of poulard wheat *Blanco de Corella*, lowest results is associated with *Soandres Laracha X Involcable* with 73 % of maximum rating. This underline the interest of context-specific bread-making test in the case of landraces baking quality assessment. The results do not show any apparent link between varieties breeding origins (commercial/landrace) and baking quality, according to chosen descriptors.

This conclusion is linked with sourdough fermentation and relatively soft kneading process. Even if it was not the purpose along this work (landraces are mostly used by bakers using « soft technics »), it could be interesting to rate the same samples with similar descriptors but with industrialised baking process (such as BIPEA test).

When most influential variables are extracted from global analyse (table 19), baker's rating influence is emphasized for POP2 from Florent Mercier's collection (drop from 1st to 13th rank). Within tender wheat « pure lines » and crossings, this discrimination underlines good baking quality of *Saint-Priest et le Vernois Rouge* and apparently bad baking quality of S*oandres Laracha X Involcabl*e.

5.1.3. Tasting

In test 1, it seems that the main factors distinguishing samples is the bread-making process. It would explain distinction between the group made of *Alauda*Rojo de Sabando* and *Saint Priest*Bladette,* appart from breads baked by other bakers (*painvirgule* and *nicolas).* Terroir seems to have less influence than bread making as *painvirgulepannif* sample was not cultivated in Bouchemaine but in richer soil of Combrée. We can also assume that poulard wheat bread taste differs from tender wheat. A recent specific INRA study on tender and poulard wheat influence on bread and pastas taste supports this assumption (Raquel Martin, expected publication in 2016). This ranking of factors influence (bread making > (species >) terroir > landraces) is compatible with Camille Vindras thesis results (Vindras-Fouillet and Chable 2014(1)).

According to Napping®2 results, taste appears more influenced by environment than genotype. This is expressed by the proximity between bread resulting from Florent Mercier's wheat (grey circle on graph 12) and especially between wheat samples cultivated in exactly the same conditions (black circle on graph 12) on the Dim1-Dim2 plan. This latter (POP1FLMC and POP2FLMC) were both cultivated the same year (2015), in the same plot with the same cropping operations (inter-row ploughing) and preceding crop (4 years grassland). Even if these samples are spread along Dim3, this last dimension explains less data structure (14%) and is partially constructed with texture words, so that it does not refute completely our assumption.

To deepen terroir effect, it could be relevant to ask basic questions on farmers practices and pedo-climatic conditions of their plots. We can assume that wheat dynamic populations, because they are composed of various cultivars, are more subject to environment variations since the genotype is itself influenced by its own environment. In theory, the longer a dynamic population has been cultivated in a given environment, the more specific is its genotype to this farming system (soil climate, cropping operations…).

5.2. Postmortem documentation

After having presented issues, and results of the investigated question, this part aims to give a specific feedback on methodology success and limits of the thesis work.

5.2.1. Agronomic work

At first glance, CAB-program represented a major asset to investigate our research question as we benefit from some years observations on various landraces. The database managed for 5 years is probably one of the heaviest of the various French participative breeding programs. However, inquiring this database, we realise the disequilibrium of global dataset:

- Varieties cultivated between 2011 and 2016 changed over time. Some were already excluded for their agronomic weaknesses (e.g. Sixt/Aff, Oulianowska, Barbu du Mâconnais) while others appeared after some years reproduction (e.g. Bladette de Provence X Saint Priest et le Vernois Rouge, Alauda X Rojo de Sabando), what makes rare varieties observed 3 times or more.

- As strategy can evolve over time in a participative program, measurement and treatments evolved last years. This also compelled us to exclude some varieties/site from our analysis.

This explains heavy information loss between varieties initially present (table 5) and the ones finally tested statistically (part 4.1). Between these two parts, we thus tried to maximise number of data tested under constraint of information reliability.

Even if statistic test mostly accept null hypothesis over 95 % confidence, field observations were sometimes noticeable (especially lodging). Observers training and extreme marks calibration may help to get higher amplitudes between minimum and maximum marks for holding, covering and lodging. This could potentially increase null hypothesis rejection frequency.

To increase number of data tested, facilitate results interpretation and data exploitation by farmers and other CAB decision makers, we gathered collected marks into three large categories : weeds suppressiveness, resistance to damages (only lodging according to data available lasts years), and economic profitability. The first one was introduced by weighting descriptors of interest according to bibliography information. Even if it seemed quite fitting this year (in comparison with field general observations), this may be adjusted over years of experimentation. This unfortunately excludes some descriptors such as protein rate, specific weight, or ear emergence date.

Because precocity observation is time consuming (7 days overall in 2016), this specific CAB requirement represented a disproportionate investment to answer our research question. In the future, precocity ranking process should be reviewed to increase cost efficiency, especially considering the regional political willingness to reduce organic research subsides.

Regarding to the issue of this work, it is difficult to say that data measured is representative of PdL organic farmers soil and practices. Indeed, even if 4 different sites were measured since 2011, data available was not always exploitable. Moreover, these 4 sites are probably not able to represent the whole diversity of terroir of PdL region. Some advices will be given further to produce better results on this aspect (part 5.3.3).

5.2.2. Baking tests

Overall, we made the most of occurring opportunities to plan baking tests along the six months of our study. This enable bargain data acquisition. Thanks to Triptolème preliminary constitution of appropriate bread-testing sheet and descriptor definition, we could produce reliable observations for each tests.

Considering the given timeline, it was not possible to plan any meeting to find a consensus on dough assessment between experimental bakers, as it was the case when this test was performed for PaysBlé study. This makes difficult data gathering for each varieties and it would be relevant to test reliability of results implementing other tests with bakers accustomed to assess Triptolème's descriptors. Anyway, results presented here should be completed by others tests to be confirmed. Then, it seems essential to carry out other tests with the same varieties cultivated in other conditions (years and environments). This implies deep changes in CAB program management because only Florent Mercier contributed to microplots implementation of « pure-lines » or crossed landraces today.

5.2.3. Sampling

Along the work, we tried to benefit from CAB-program events to optimise sampling costs. That is how we managed to carry out two Nappings® sessions with more than 10 persons each. However, such opportunities imply obedience to defined rules (for example, there were already some flour samples collected by GAB44 during the first test). In the case of test 1, the 3 others samples tested (not presented in methodology but on graph 11), because they came from other environments, stored different way, may influence considerably the taste of resulting bread, what reduce data reliability.

Because of time limits, no training was carried out to get objective data of a trained panel, as it was the case in pluriannual relative works (Vindras-Fouillet et al. 2014(1)). Panel constitution, even if it has already been initiated, cannot provide so far any data on landraces discrimination. We can expect first data to be available in 2017.

5.3. Program perspectives

Each 3 years, CAB raises funds to maintain breeding program running. The program is financed 50% by PdL regional subsides (agriculture research) and 50% is self-financed. Next fund raising will occur on the 15th November and the demand will be accepted or refused on the 15th February 2017. Political changes in 2016 regional elections cast doubt in program financing (some others programs having usually their subsides renewed were not financed this year). For this reason, we can suspect partial or entire subsides suppression.

More generally, recent legislative context changes (as described part 1.2.3.3) will probably foster landraces exchanges in France and especially in regions such as Pays de Loire, where farmers already started to sow this varieties for a couple of years.

Finally, attendance of bakers during last communication CAB-program day (on landraces dispersal issues) and the abundance of demand (21 tons request unanswered on the 22/09/2016, on an on-line landraces exchange page upload by CAB for farmers) let think that landraces grain demand is currently increasing.

To insure farmers access to adapted landraces, CAB decision-makers need to find creative and cost effective way to renew the breeding program next years. In this part will be presented some ideas to support their reflection.

5.3.1. First step breeding : collection microplots

Even if collection does not represent so much interest on the short term, it present two major assets for CAB-program as a whole :

- Centralising numerous microplots (conservatory, crossings, F2 selections) facilitate comparison, multiplication of interesting cultivars and rejection of inappropriate ones. Thus, collection can enable discovery of new interesting traits in wheat landraces from diverse origins (countries, breeders, induced crossing, selected mutants). It is of great interest to promote and explore wheat diversity for many reasons already exposed in part 1.1.2.
- Diversity of species, shapes and colors within collection is attractive for people willing to learn about landraces. The first step of CAB program is thus a good opportunity to communicate on wheat landraces, cultivated biodiversity and organic farming issues to the general public (what is one of CAB missions).

For this reason, it would be relevant to keep this program step running. If necessary, costs could be reduced by lessening the time spent for ranking varieties. It would then be relevant to maximise cost efficiency and resulting information by choosing appropriate descriptors for each category. Ranking height of taut straw, lodging (diseases specific years of infestation) and yields would be sufficient to get general information regarding weeds competition, damage resistance and economic profitability. The first two marks were already briefly observed by Florent Mercier once before harvest, registered as “global mark” (today, this last mark influences very much breeding choices).

The third one simply requires to weigh each bag (1 bag/plot) of harvested and sorted grain. Applying this advices would dramatically reduce costs with almost no information deterioration.

5.3.2. Second step breeding : observation strips

As exposed on figure 6, 3 pilot sites are today involved in the second step of the program and adopted various way of implementation (figure 7). Moving from one site to another to mark each quadrat conscientiously is time consuming (47km to go to Jarzé and 76km to go to Laigné). These observations were performed to give information on landrace*environment interaction but the resulting synthesis is poor. That's why we propose to make clear distinction between step 2 and step 3 observation purpose and commitment. Each varieties of interest would be observed only on one site. To justify scientific approach (essential to raise funds), in-depth ranking would be performed to test statistic difference between varieties strips. To calculate standard deviance for each varieties, 3 repetitions / cultivar could be carried out.

To reduce costs, some marks could be removed or simplified, as detailed in table 21.

Table 21: Recommendations for observation strips ranking.

Descriptors	To be conserved	To be simplified	To be removed	Recommendations
Winter losses (%)		x	x	3,5 days in 2016. 10-15% of weed suppressiveness information. It could be removed or specifically observed for harsh winter years.
Holding (1 to 5)	x		x	2 days in 2016. 15-20 % of weed suppressiveness information. Could be removed or conserved.
Covering (1 to 5)	x			2 days in 2016. 30-40 % of weed suppressiveness information.
Height in april (cm)			x	2 days in 2016. No interest if height at maturity is observed.
Leaf yellowing			x	0,5 day in 2016. No concrete interest for farmers
Height in mai (cm)			x	2days in 2016. No interest if height at maturity is observed.
Ear emergence date		x		7 days in 2016. Very time consuming when wheat are observed from earing beggining to earing end. Only the date of first ear emerged should be registered.
Rust sensitivity	x		x	Diseases should be marked when years are conducive for infestation. This kind of notation should be performed by experimented people.
Number of mature ears			x	No interest if grain yield is measured.
Height of taut straw (cm)	x			1,3 day in 2016 (together with lodging marks). 30-40 % of weed suppressiveness information.
Height of curved straw (cm)			x	No interest is height of taut straw is measured.
Lodged wheat by field (%)	x			1,3 day in 2016 (together with height of taut straw). These two marks are used to calculate global wheat lodging index.
Lodging index (1 to 5)	x			
Grain humidity (%)			x	No interest for varieties distinction.
Grain yield (qt/ha)	x			Time difficult to estimate since it includes harvest and grain sorting. However, these steps are anyway realised by farmers. Very time consuming when quadrats are individually harvested (4 days with two persons). A process should be designed to get 3 repetitions by varieties without harvesting specific quadrats.
Straw yield (t/ha)	x		x	In 2016, it was easy to measure since straw was sorted from weed by some participant to a CAB-event. To be measured only if no added time is required.
Specific weight (g)	x		x	In 2016, could be measured simultaneously with protein rate (same measurement tool). To be measured only if no added time is required.
Protein rate (%)	x			0,6 days in 2016. To be measured if we benefit from free access to measurement tools.

Eventually, it could be interesting to move step 2 observation strips from one farm to another (every 3 years or more) in order to get indications on varieties performances between different soil/ farmer practices. However, year influence should be tested and step 3 seem more suitable for terroir adaptation ranking. Moving from one site to another could induce costs increase and can be triggering (engine secondment, implementation protocol).

Step 2 is the most expensive step of the program. It procures statistically usable data enabling CAB to raise funds. However, if no regional subsides are allocated to the program, marks could be restricted to step 1 ones, described in preceding part (part 5.3.1) and performed by Florent Mercier or anybody able to do so.

5.3.3. Third step breeding : open fields

2 years ago, contracts between farmers and CAB were signed. CAB gave landraces seeds freely and farmers were supposed to give a feedback on various descriptors about the given varieties, what did not work properly. We can assume that the lack of farmers feedbacks is explained by ranking difficulty or time-consuming.

Today, even if CAB sometimes get global satisfaction of farmers regarding *Population dynamique n°1* and *Population dynamique n°2* cultivated in their fields, information is fuzzy and sporadic. At a time when new varieties (landraces multiplied crossing and lines) are up to be cultivated in fields (>3000m²), it seems essential to generalise and make the most of farmers feedbacks.

To insure relevance and abundance of farmers observations, implementing a clear process would be profitable :

- The first essential point is to register precise data on wheat area of cultivation. Each farmer should fulfil cases to describe soil texture, preceding crop(s), tillage, fertilisation, seeding date and density, and grain yield potential for varieties usually cultivated by him (mentioning the name and/or complementary information on these varieties). These data should then be classified in some categories representing PdL terroir diversity to make data testable statistically. Statistical test will probably not be possible next year since the quantity of seed must be sufficient to cultivate each varieties on 3 farms for a given year and category (approximately 30kg/varieties/years/category).
- Farmers should be assisted in trial implementation and harvest to make sure that left

varieties are conserved throughout multiplication. A protocol sheet could be established and distributed to these farmers with informations on seeding density and bias to avoid (e.g. proximity with hedges, grain contamination at harvest).

- It would be very expensive for CAB intern or employee to go from farm to farm to observe varieties. For that, ranking should be carried out by farmers and reduced to the ones of step 1 (part 5.3.1), maximising thus relevance under time consumption constraint. To standardize farmers appraising, extreme examples could be presented as reference and/or a training course could be proposed by CAB animators. Various courses (financed by VIVEA funds) are indeed provided along the year and the newly constituted “farmer-bakers group” could be a rallying point for such training, inducing no extra-cost.
- Harvest would require specific attention because it is a key period both for quality of reproduced seeds, and consistency of notation (quality + quantity). Indeed, all marks in this step are registered at wheat maturity. Approaching of this date, CAB animators should call farmers to remind them how to perform notation, harvest trials and to give their feedback as soon as harvest is done and grain is sorted.

This step, if properly conducted, could dramatically benefit academic knowledge on wheat population dynamics, and make the most of participation potential of CAB-program. In this way, CAB-program could serve as reference for other French participative wheat breeding programs. It is a way to better represent diversity of soil and practices of PdL organic farmers.

6. CONCLUSION

This study aimed to summarise wheat landraces agronomic observations carried out since 2011, especially for farmers interested in finding and breeding genetically heterogeneous varieties adapted to their farming system. It also introduced new field of study regarding end-products quality (baking quality and taste) to foster landraces diffusions to millers, bakers and others food processors, namely to ease stakeholders cooperation within PdL food systems.

With the purpose of simplifying indicators to help action-oriented decision-making by farmers, we gathered variables observed for some years by CAB. This led to rank varieties according to three field indicators : weed supressiveness, damage resistance (reduced to lodging resistance in this study because of data restriction) and economic profitability. We proposed a specific synthesis of year 2016 as varieties cultivated this year are supposed to be the most interesting since 2006 (breeding program launching). We tried to confirmed statistically these observations using data available for 5 years. Unfortunately, data disequilibrium and varieties changes over years did not enable to highlight major statistic differences between landraces cultivated in 2016. Even if difference were easily observable in the field, these were rarely proofed statistically. First results regarding terroir adaptation could be established : the *Population dynamique n°2* (mix of 5 landraces in 2012), less productive than *Mélange commercial de Laigné* (mix of 3 commercial varieties) in productive context, seems however more productive in poor context (less than 95 % confidence).To make statistic differentiation easier, some notation should be reviewed and varieties should be marked 3 times each every year. Rough data must be conserved in a unique database to keep the same data structure every years. Since diversity of terroir is high in PdL and because CAB program is up to benefit from sufficient landraces grain quantity to spread seeds, some other years seem required to answer our sub-question : “are wheat landraces adapted to PdL farming contexts ?”. Farmers involvement into CAB breeding program seems essential to maintain this research work in its original mission : to be participative.

Baking tests do not report high differences between landraces and commercial varieties tested. We can assume that baking practices employed in our baking test (sourdough, slow kneading, hand-shaping) are more appropriate than BIPEA test used to subscribe new varieties to French Official Catalog of Seeds and Plants. This conclusion leads to reconsider landraces use for food-processors using these baking practices. In this way, we assume that landraces are a promoting factor of exchange between peasants and local craftspersons in local food systems.

So far, sampling do not report any specific difference between landraces. It seems that terroir influence more bread taste than varieties. However, this last conclusion is the result of two dynamic populations differentiation, which are supposedly more subject to site adaptation (within a population, the varieties more adapted supplant the others). These conclusions answer partially our second sub-question : “are wheat landraces suitable for bread making and selling?”. Ours results will be deepen next years with the current implementation of a specific group of discussion composed of farmers who bake bread and by the training of panellists to taste breads. Results of this panel could be popularized to educate consumers and promote local bread diversity through taste objectification.

More generally, even if statistical difference is essential for scientific knowledge, it is not always the case for field stakeholders decision making. For this reason, encouraging CAB program participants to use the presented results in their choices for varieties on the short-term, we proposed also a program review for next years. Our propositions aims to give statistical results between varieties of interest each year (only one pilot site for fine observations), and some indications on varieties*environment interactions (involving new PdL farmers in this participative breeding program). For this reason, our work can be seen as a summary of last years experiment, but also as the starting point for new orientation fostering participation by farmers and considering food-processors objectives, keeping alive agroecological founding principles of this research program.

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Figures

Tables

ANNEXES

Annexe 1 : Forward plan

Annexe 2 : Bread-making tests diagrams

Annexe 1 : Forward plan

Tasks	Hours	March					April			Mai				June					July				August					September				October	
VARIETIES OBSERVATIONS	213,3	13	14	7,4	6,3		2,4	5,6	0	2,3	12	9,9	12	16	3,4	1,7	0	0,5	0	0	16	9,3	30	29	20	3,8	0	0	0	0	0	0	0
Wheat counting after winter	24,8	4	11	2,5	4,8		2,4																										
Weeding + quadrat placement	14,8	9	1	4,3	0,5																												
Holding and height	16,48		1,8		1			5,6		2,3	5,9																						
Earing and covering	49,5										6,2	9,9	12	16	3,4	1,7																	
Diseases	0,7			0,7																													
Height and lodging	9,0																	0,5			8,5												
Bouchemaine pilot site harvest	63,6																				7,1	8,3	21	24	3,8								
Laboratory analyse	4,5																								4,5								
Collection varieties sorting	30,1																					1	8,8	4,8	12	3,8							
BREAD MAKING TESTS	111,1	0	1,8	0,2	2,3		0,8	8,8	6,3	0	0	0	1,2	3,3	19	5,1	0	25	0	0	10	0	0	0,3	0	24	3	0	0	0	0	0	0
Protocole design	13,0		1,8	0,2	2,3			8,8																									
Bread making	63,0												1,2	3,3	8,4	1,4		22								24	3						
Sampling	35,1						0,8		6,3						11	3,7		3			10			0,3									
COMMUNICATION AND EVENTS	156,2	0	0	0	1,5		0	9	9,7	22	11	9,9	7,3	4,8	2	0	4,6	15	15	0,5	12	33	0	0	0,6	0	0	0	0	0	0	0	0
Interviews	46,1				1			5	2,5	16	11	5,3	3,2	3																			
Participatory weeding	11,8				0,5			4	7,3																								
Collection visit	53,3									6,3		4,6	4,2	1,9	2		4,6	15	15	0,5													
Participatory harvest	45,1																				12	33			0,6								
SYNTHESIS	95,6	13	2,5	4,5	0		4	6,6	0	0	9,6	7,7	2,1	4,4	4,9	0	5,9	0	15	7,7	0	2,5	0	0	0	0	6,3	0	0	0	0	0	0
Data gathering	23,5	13	2,5	4,5			4																										
Statistical analysis	72,1							6,6			9,6	7,7	2,1	4,4	4,9		5,9		15	7,7		2,5					6,3						
WRITING	449,9	4	11	20	21		24	0	0	4,7	0	2,5	14	8,2	6	15	21	2	5,8	6	0	0	0	11	12	6,7	23	31	41	41	0	0	0
2015 synthesis	18,7						19																										
Pilote site drawing	14,3		8,5	1,5						1,9				2,5																			
Communication flyers design	0,8						0,8																										
Pre-report	49,0	4	2	17	21		5																										
Report	200,8									2,9			14	5,8	6	15	21	2	5,8	6				11	12	6,7	23	29	41	41			
Referent meeting	5,1			1								2,5																1,6					
Restitution																																	
OTHERS	80,6	6,8	6,8	5,2	0		4	3,9	5,6	0	1,2	0,9	4,2	1,6	2,2	1,6	1,5	1,3	4,3	8,8	8	6,3	2,3	1,3	1	0,5	1,6	0	0	0	0	0	0
Varieties ordering and naming	3,5		1,5	2																													
Biotope GABBAnjou article	0,3		0,3																														
Planing/transition	24,0	6,8	5	0,9			2	2,5	3,7				3,2																				
Learning	7,0																			7													
Emails and file ordering	33,9			2,3			2	1,4	1,9		1,2	0,9	1	1,6	2,2	1,6	1,5	1,3	4,3	1,8	1,7	0,5	2,3	1,3	1	0,5	1,6						
Stock management	12,0																				6,3	5,8											
ASSOCIATIVE WORK	13,8	0	0	0	0		0	3,8	0	0	0	0	0	0	0	0	6	0	0	0	0	0	0	0	0	0	1	3	0	0	0	0	0
GABBAnjou board of directors	10,8							3,8									6										1						
Cereals technical meeting	3,0																											3					
PUBLIC HOLIDAYS					7					7		7													7								
GLOBAL	1 040	36	35	37	38		36	38	22	36	33	38	41	38	38	23	39	43	39	23	45	51	32	41	41	35	35	34	41	41	0	0	0

Annexe 2 : Bread-making tests diagrams

Triptolème test	2 – POP2JLC	2 – POP1JLB	2 – POP1PRF	2 – POP1FLMC	2 – POP1SMP	2- POP2JPJ	2 – POP2FLMC	2 – POP2LMR	2 – POP2FLM
Flour mass	1800								
Flour temperature	26								
Water mass	980	1010	985	1020	1000	1050	1000	1100	1070
Water temperature	24								
Salt mass	45								
Sourdough mass	750								
Kneading duration	6min								
Kneading description	Manual								
Dough temperature	25	25	24	24	24	24	24	24	25
1st fold time	X	X	X	X	X	X	X	X	X
2nd fold time	X	X	X	X	X	X	X	X	X
division time	13:40	13:47	13:51	13:57	14:04	14:10	14:16	14:21	14:27
shaping time	13:40	13:47	13:51	13:57	14:04	14:10	14:16	14:21	14:27
Lumps mass	350	337	328	340	333	350	333	367	357
Fermentation duration (h)									
Proofing duration (h)	2,02	1,93	1,90	1,83	1,75	1,68	1,60	1,55	1,48
Proofing temperature	26								
Loading time	15:41	15:43	15:45	15:47	15:49	15:51	15:52	15:54	15:56
Baking temperature	260 – 200	260 – 200	250 – 200	250 – 200	250 – 200	250 – 200	250 – 200	240 – 200	240 – 200
Pushing time	16:20:00	16:20:00	16:19:00	16:19:00	16:18:00	16:18:00	16:17:00	16:16:00	16:16:00

Triptolème test	3 – HEN	3 – REN	3 – PRI	3 – BLAPRI	3 – ALASAB	3 – POP1FLMC	3 – POP2FLMC	3 – SOAINV	1 – BLAPRI	1 – ALASAB	1 – COR
Flour mass	2 500,00								3200		
Flour temperature	25,70										
Water mass	1600 + 125								2200		
Water temperature	22,70										
Salt mass	60,00								60		
Sourdough mass	1 000,00								900,00		
Kneading duration	10min + 4min								3min		
Kneading description	Batteur. Kneading + water incorporation								Manual		
Dough temperature	26,6	26,9	27	25,9	26,6	26,8	26,3	28,2			
1st fold time	11:03	11:15	11:25	11:45	11:49	12:05	12:15	12:35	13:07	13:11	13:15
2nd fold time	11:48	12:00	12:10	12:30	12:39	12:50	13:00	13:10	X	X	X
division time	11:54	12:57	13:17	13:48	13:51	14:05	14:11	14:17	14:22	14:26	14:30
shaping time	13:04	13:08	13:42	14:04	14:08	14:22	14:31	14:40	14:38	14:42	14:45
Lumps mass	500								750,00		
Fermentation duration (h)	2,77	2,60	3,03	3,07	3,07	2,95	3,02	2,83			
Proofing duration (h)	3,68	3,70	3,22	3,60	3,62	3,47	3,40	3,33	1,25	1,25	1,25
Proofing temperature	4	4	4	4	4	4	4	4			
Loading time	16:45	16:50	16:55	17:40	17:45	17:50	17:55	18:00	16:06	16:09	16:12
Baking temperature	Voûte = 255°CSole = 260°C										
Pushing time	17:25:00	17:30:00	17:35:00	18:30:00	18:35:00	18:40:00	18:45:00	18:50:00	16:54:00	16:57:00	17:00:00