



PROMAÏS AND AMAIZING: AN OVERVIEW OF PPP RELATED TO MAIZE GENETIC RESOURCES IN FRANCE SINCE 35 YEARS

PPP - ECPGR

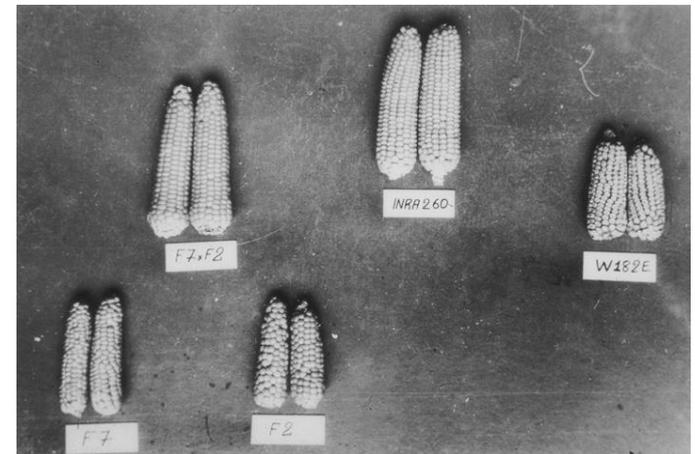
Bonn June 8th, 2017



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Carine Palaffre, Cyril Bauland, Maryse Carraretto,
André Gallais Antoine Lambert, Jean Beigbeder

Two key steps for maize in France

1. Introduction after discovery of Americas, local adaptation of original Open Pollinated Varieties (Landraces), with Flint (vitreous) endosperm,
2. Development of hybrids by INRA after WW2, first by crossing European Flint inbred lines (climate adaptation) with North American Dent ones (yield potential)
-> development of a very active private sector (init. cooperatives)



Replacement / preservation of traditional varieties

- Replacement of traditional varieties (populations) by commercial hybrids in the 1950s-70s
- Collection of 270 populations before replacement/extinction
 - First phase: search for sources for new inbred lines
 - Second phase (70s): more formal prospection in Pyrenean valleys before total disappearance

*Conservation remained unformal until the early 1980s
-> risk factor for long term maintenance*

Starting the INRA-Promaïs partnership on genetic resources

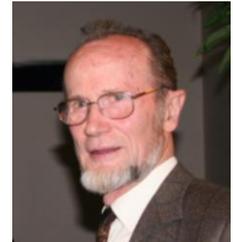
- Pro-Maïs association started in 1969 under the leadership of JP. Monod and A. Cauderon to promote private-public cooperation in maize genetics/breeding (25 companies, now 9)
- Genetic Resources Network initiated by A. Gallais and J.-P. Monod, managed jointly by INRA and Pro-Maïs since 1983:
 - ✓ INRA contributes to multiplication (Saint-Martin), keeps the resources in two cold chambers (security) in Montpellier: 4°C short term and – 20°C long term. INRA manages also the database SIREGAL (next slide) and distribution
 - ✓ Pro-Maïs members contribute to multiplication (approx. 2/3) and finance research projects about maize genetics, history and breeding.



A. Cauderon
(INRA)



J.-P. Monod
(Promaïs)



A. Gallais
(APT-INRA)

1236 populations maintained in total

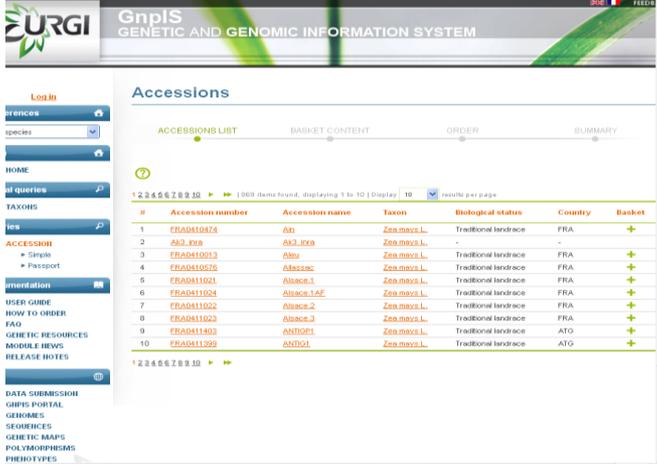
- ✓ 270 from Metropolitan France, 113 from Caribbean
- ✓ 140 synthetics
- ✓ Other introductions

First two categories (+ 15 inbred lines) define the French National collection, declared in TIRPA available to all with SMTA since 2009

Can be ordered through INRA SIREGAL information system

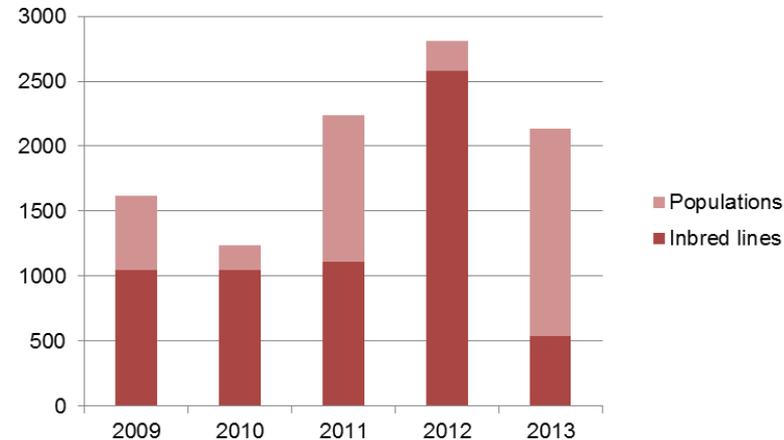
<https://urgi.versailles.inra.fr/Projects/Achieved-projects/Siregal>

Rk. INRA also maintains a working collection of approx. 3500 inbred lines at Saint Martin de Hinx station



The screenshot shows the GnpIS web interface with a table of accessions. The table has columns for accession number, accession name, taxon, biological status, country, and basket status. A green arrow points from the text 'Can be ordered through INRA SIREGAL information system' to the 'Basket' column of the table.

#	Accession number	Accession name	Taxon	Biological status	Country	Basket
1	FRAD110474	A11	Zea.mays L.	Traditional landrace	FRA	+
2	AK3_FRA	AK3_FRA	Zea.mays L.	-	-	-
3	FRAD110113	A80	Zea.mays L.	Traditional landrace	FRA	+
4	FRAD110210	A80c	Zea.mays L.	Traditional landrace	FRA	+
5	FRAD110211	A80c.1	Zea.mays L.	Traditional landrace	FRA	+
6	FRAD110214	A80c.1AF	Zea.mays L.	Traditional landrace	FRA	+
7	FRAD110222	A80c.2	Zea.mays L.	Traditional landrace	FRA	+
8	FRAD110223	A80c.3	Zea.mays L.	Traditional landrace	FRA	+
9	FRAD111403	AND01	Zea.mays L.	Traditional landrace	ATG	+
10	FRAD111309	AND01	Zea.mays L.	Traditional landrace	ATG	+



Distribution statistics

Information on populations available on Promais website : <http://pro-mais.org/>

Préservation des ressources génétiques et recherche scientifique sur le maïs

PROmaïs
ASSOCIATION POUR L'ÉTUDE ET L'AMÉLIORATION DU MAÏS

L'association Programmes de recherche Ressources génétiques Variétés de pays Histoire et sélection du maïs

Une association dédiée à la génétique du maïs

La conservation des ressources génétiques du maïs

Le maïs et les hommes une longue histoire de culture et d'amélioration

Des programmes de recherche sur la biodiversité du maïs

273 variétés anciennes de maïs accessibles à tous

Semences et biodiversité

PHOTOTHÈQUE AGENDA CONTACT MENTIONS LÉGALES ACCÈS MEMBRES

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Variétés de pays > Variétés de pays françaises

Les variétés de pays françaises

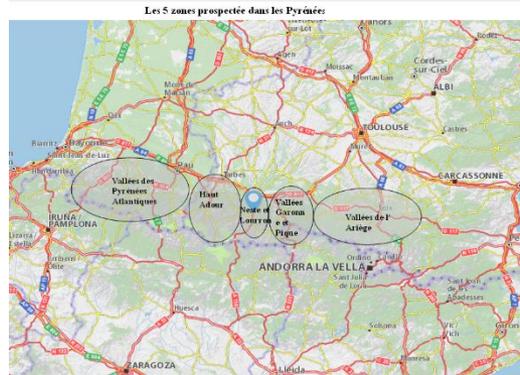
Introduction
 Variétés de pays françaises
 Populations pyrénéennes
 Recettes du pays

Nom dans la collection	Lieu de collecte	Dpt.
Ain		01
Aleu	Aleu	09
Allasac	Allasac	19
Alsace.1		68
Alsace.1AF		68
Alsace.2		68
Alsace.3		68
Argein	Argein	09

Completed by an ethnobotanical survey of the Pyrenean valleys conducted by Maryse Carraretto

Interviews in 2012-2013 of 73 women and men having been involved in traditional varieties cultivation and use in locations of origin of the accessions maintained (70 to 93 years old)

- ✓ Maize cultivation methods
- ✓ Seed reproduction, introductions, conformity of collection samples
- ✓ Use for food and feed
- ✓ Transition to hybrids
- ✓ Free expression



(from *Le maïs et sa culture en Béarn*)

Synthesis with local language lexicon available on website, book by M. Carraretto and J. Beigbeder to be published soon

Research projects: 1. Promaïs

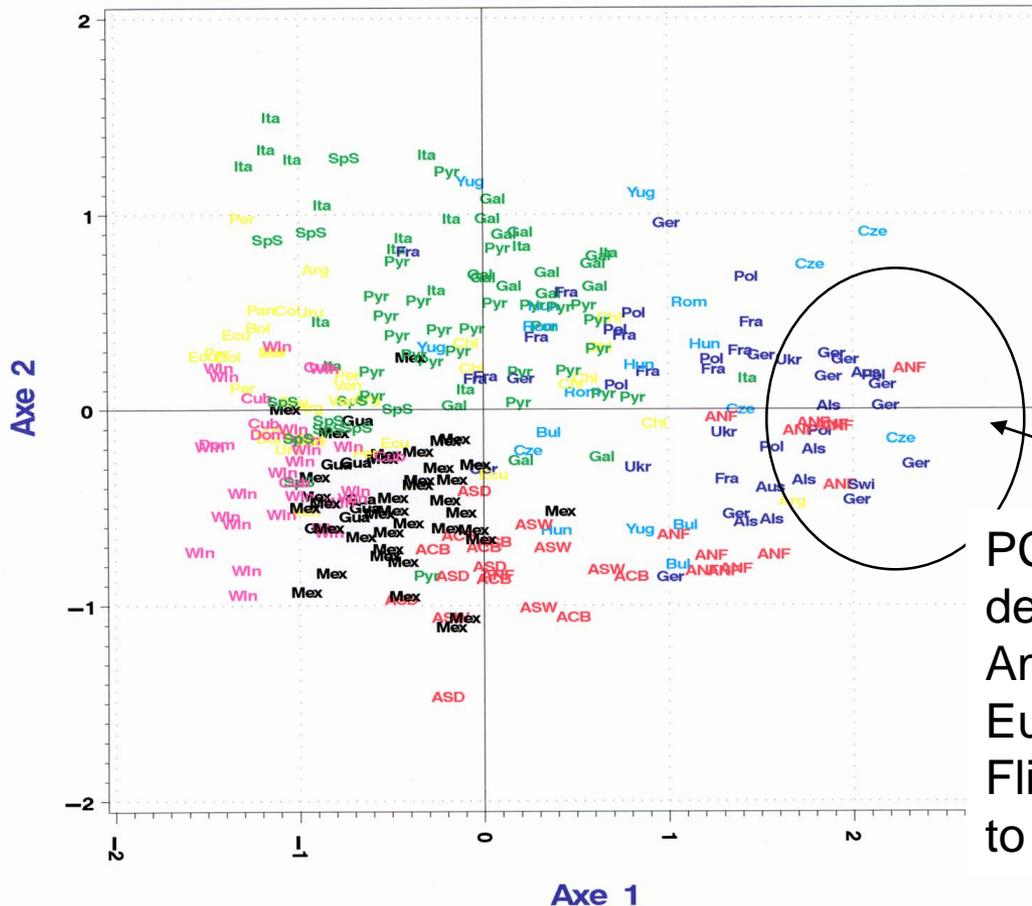
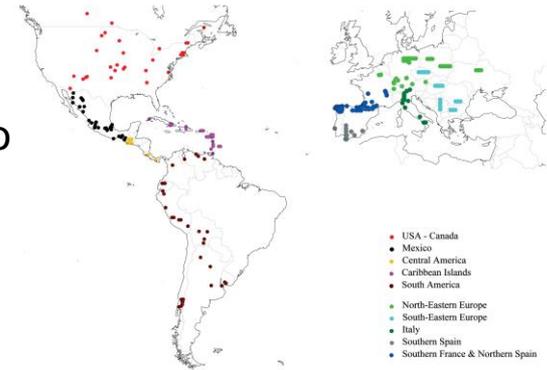
- Participation of Promaïs members on a voluntary basis (generally 6-9 / 9)
 - INRA labs: staff and infrastructure
 - Promaïs members: field experiments, genetic material development, consumables for work at INRA, temporary staff
 - Supported or not by external funding (CTPS, EU for RESEN88)
- Main topics covered:
 - genetic diversity analysis at molecular and phenotypic levels: Populations sources (PPS): PPS2 et PPS2C, Diversité corné 1, 2, 3, RESGEN88, diversité Zea
 - breeding methods (pre-breeding): “Piémont Pyrénéen”, valorisation ressources génétiques”
 - Breeding methods (marker assisted): SAM, SAMMCR 1, 2.
 - study of quality and adaptive traits

INRA –Promaïs program« Population Sources » (A. Gallais, J.-P. Monod et al., 1983)

- 1236 populations evaluated for their combining ability with testers, field experiments by private partners
- Creation of 32 pools of materials sharing good (broad pools) or very good (narrow pools) general or specific combining abilities
- Creation of improved versions of pools enriched with elite INRA materials with similar specific combining abilities, followed by tester based selection -> some families superior to checks
- Distribution of pools to private breeders for internal breeding

Organization of diversity using molecular markers (PPS, diversité corné, diversité Zea)

here 24 SSR, coop. CIMMYT, Dubreuil et al., 2006, see also Dubreuil et al., 1998, Rebourg et al., 2003, Mir et al., 2013, Brandenburg et al., 2017



America:

- Mexico - Guatemala
- USA - Canada - Chili
- Caribbean
- Southern America

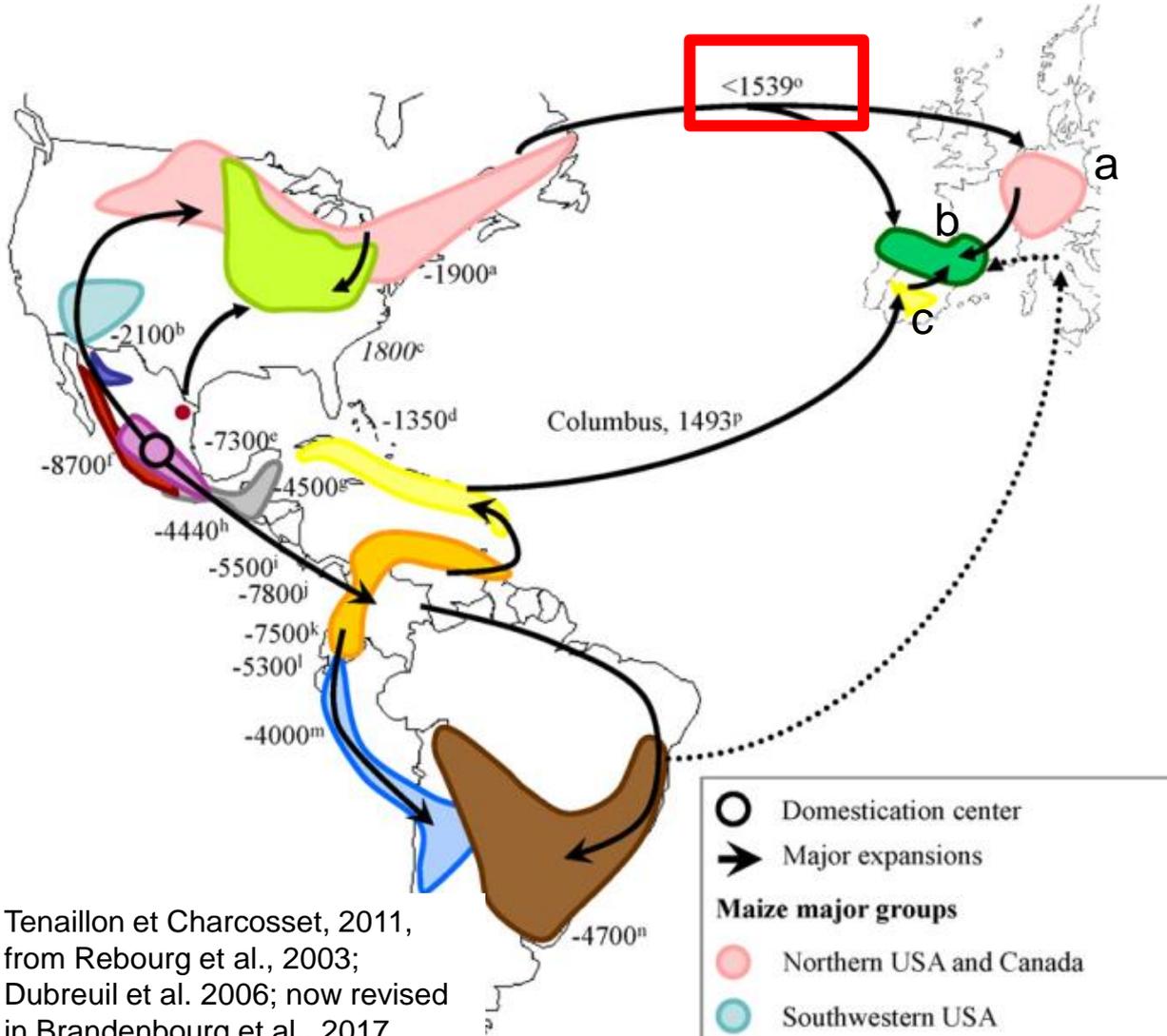
Europe:

- Spain – Pyr - Italy
- France– North-Eastern
- Balkans

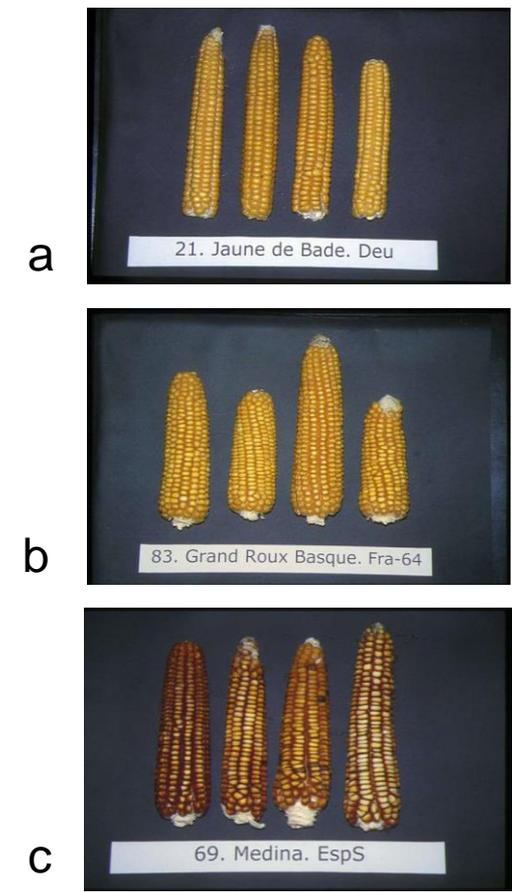
PCA1 is determined by American and European Northern Flints, as opposed to tropical material



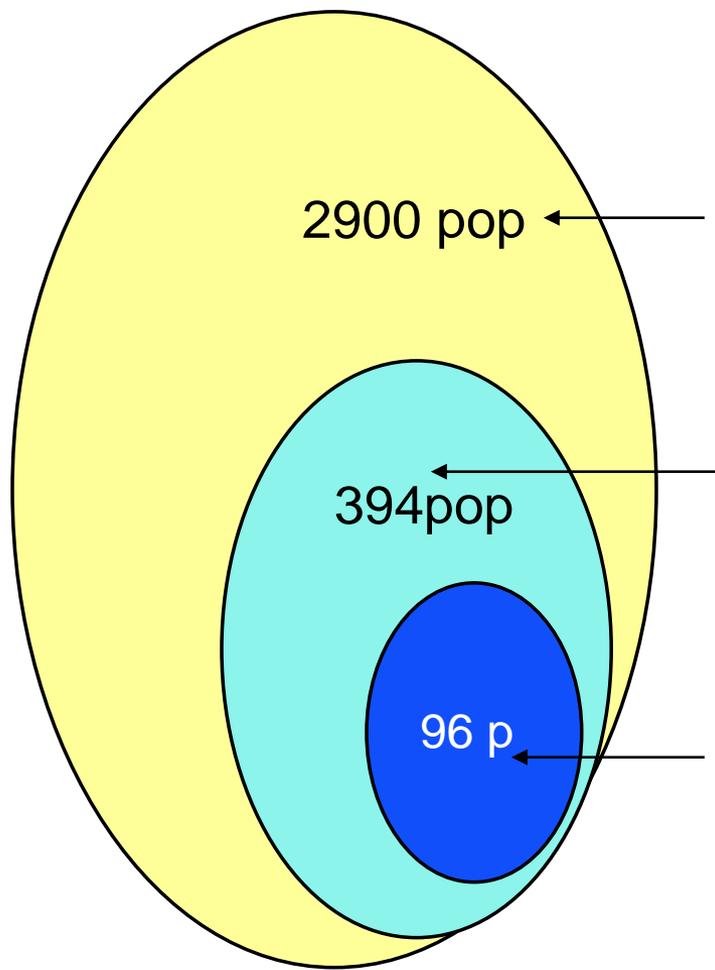
Marker and history based scheme for Maize migration / introduction into Europe (West European perspective)



Tenaillon et Charcosset, 2011,
 from Rebourg et al., 2003;
 Dubreuil et al. 2006; now revised
 in Brandenburg et al., 2017



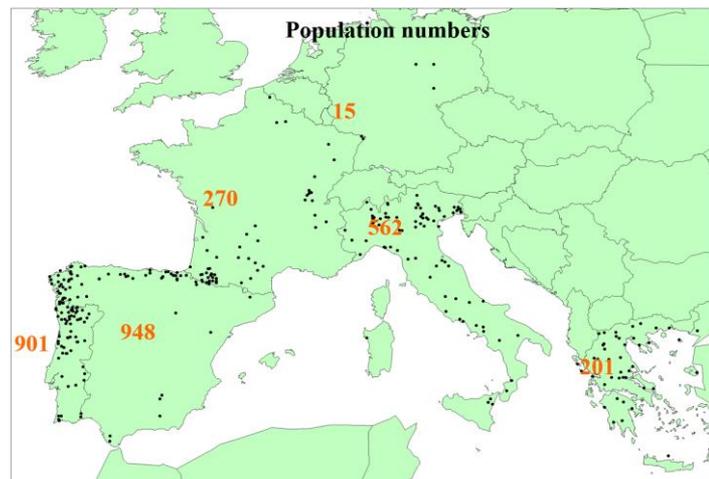
Use of markers to establish a core collection within European program on maize landraces (RESGEN 88)



Whole collection :
passeport,
primary
descriptors

National representative
collections : *molecular
markers*, silage digestibility

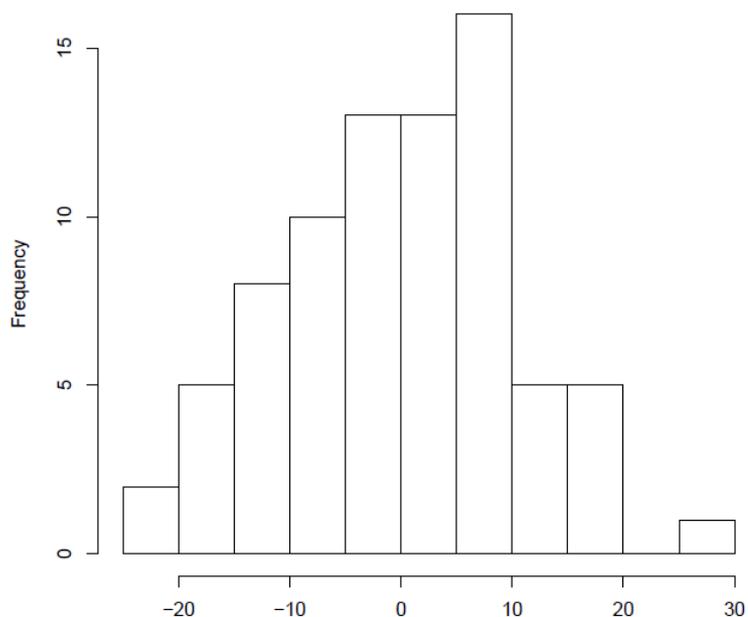
European Core collection:
adaptative traits to Europe



Trait variation in representative sub-collections

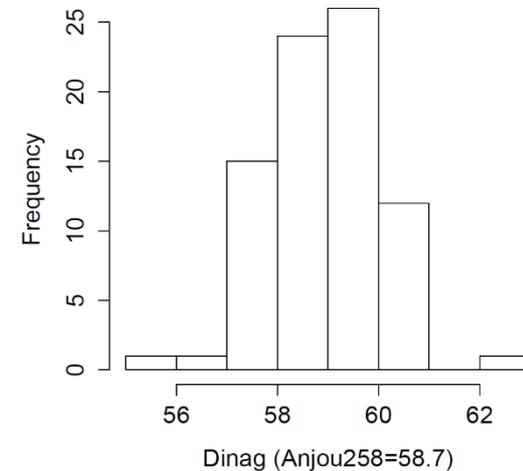
Use of passport and genotyping data to optimize representative collections

a) Drought tolerance for 78 populations from European core-collection



Index of sensitivity and performance under well-watered conditions for yield, number of kernels, LAI, ASI, number of ears for populations of INRA-PROMAIS and RESGEN88 collections (Gouesnard et al., 2016)

b) Silage feeding value (DINAG) for 88 representative populations from South-West France



Multicrop database
<http://bioweb.supagro.inra.fr/multicrop/>

Research projects: 2. Amaizing



Amaizing = Maize Integrated Genomics

- Duration: 8 years (started October 2011)
- Full cost: 27,5 M€
- Subvention: 9 M€ (ANR, "Investment for the Future") + 0.38 M€ (France Agrimer)
- 9 private companies (7 breeders: Caussade, Euralis, KWS, Limagrain, Maisadour, RAGT, Syngenta; Biogemma, GEVES), 1 technical institute (Arvalis)
- 15 public research laboratories

Main topics covered (related to PGR):

- Document sequence, structural and epigenomic variation in European maize, evolutionary implications and contributions to trait variation
- Genetics of adaptive traits, based on association genetics panels (completed by new lines during project), dense genotyping and phenotyping for adaptation (field and platforms)

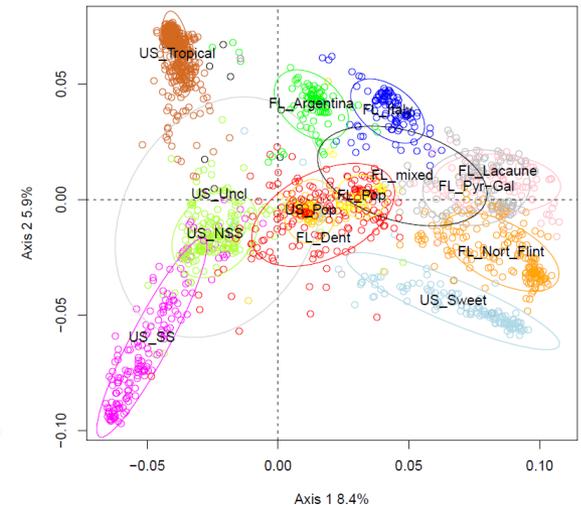
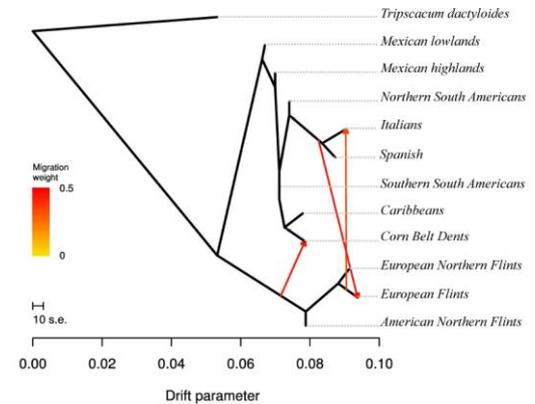


Main present achievements related to PGR

- ✓ High Throughput Sequencing (15X) of 67 lines representative of European main landraces and their putative American sources
 - > 22,294,769 SNPs
 - > *highlights importance of admixture (hybridization between introductions)* (Brandenbourg, ..., Tenailon, 2017 Plos Genetics)

- ✓ 1200 flint inbred lines from European collections / breeding programs analyzed by GBS (coop. Cornell) at 514.000 SNPs and compared with USDA collection (US_, Romai et al., 2013)
 - > *confirms the originality of European Flint inbreds, with several subgroups (Italy)*
 - > *use in association Genetics (Gouesnard et al.)*

- ✓ Use of 50k SNP array to analyze heterogeneous landraces -> *identification of diversity sources not represented in inbred lines collections / elite pools* (Arca et al., in prep.)



Both Promaïs and Amaizing projects contribute to the enrichment of inbred lines collections

- ✓ Open Pollinated Varieties present each a very broad diversity to prevent inbreeding depression
 - > evaluation of fixed inbred lines easier (see work by AE. Melchinger and CC. Schoen groups)

Towards use of genetic resources in elite breeding: Pilot scale cooperative program “Promaïs ValRG”

7 participants (INRA + 6 breeding companies)

Objective: *use of genetic resources to improve the elite Flint line parent of one top hybrid per participant, respecting its proprietary rights*

- 80 original flint lines candidate donors (from previous Amazing analysis) crossed to the elite Dent line from each participant (Caussade, Euralis, KWS, Limagrain, Maïsadour, RAGT)
- *25 trials in total*, joint analysis and discussion on criteria -> importance given to yield, earliness stalk lodging.



-> Selected donors (7) used as sources for Back-Cross populations with the flint elite of each partner to *produce new lines, with a concerted connected mating design*

-> *To be followed by evaluation of new introgressed lines with partner specific tester, joint field evaluation and genotyping to train genomic selection models for further breeding*

Conclusions

Complementary private-Public Partnership within Promaïs and Amaizing have been extremely helpful to:

- ✓ maintain collections in view of distribution and use in research
- ✓ Fund research on a regular basis (eg. Diversity analysis)
- ✓ Create new resources (production of lines from PGR)
- ✓ contribute to phenotyping
- ✓ Evaluate methods of use, including new cooperation models between companies

Build a community of scientists curious about diversity, contributing to documentation of past uses, communication, and to the orientation of research programs

Perspectives

European Maize genetic resources : what would be useful now?

- ✓ Update / complete synthesis of collections (working group reactivated since 2015, P. Revilla, V. Andjelkovic, A. Charcosset, application to ECPGR)
- ✓ Evaluate representation of populations by inbred lines, possibly expand by creating new ones (DH)^
- ✓ Evaluation of populations and inbred lines for traits of interest, association genetics^
- ✓ Propose / expand consortia for connection to elite breeding (rq. Proprietary rules extremely important)^

^ : *opportunities for Private – Public – Partnership*

Acknowledgements

Projects coordination and scientific analyses: A. Gallais, M. Lefort-Buson, A. Charcosset, B. Gouesnard, C. Bauland, S. Nicolas, M. Tenaillon

Management of collections: A. Zanetto and colleagues (Montpellier), J. Laborde then C. Palaffre and colleagues at Saint Martin de Hinx

Development of genetic materials and phenotyping: Ph. Jamin, C. Monteil, B. Lagardère, M. Bédère and colleagues

Genotyping: V. Combes, F. Dumas, D. Madur, M. Merlino, MC Le Paslier et coll.

Students et young scientists: P. Dubreuil, B. Lemoine, C. Rebourg, L. Camus-Kulandaivelu, C. Mir, R. Rincint, M. Arca, S. Rio, A. Allier, T. Mary-Huard, JT Brandenburg

Ethnobotanical and historical analyses: M. Carraretto, M. Chastanet

Private partners from Promaïs projects (started by A. Gallais and J.-P. Monod) Caussade, Euralis, KWS, Limagrain, Maïsadour, Monsanto, RAGT, Syngenta, Pioneer, *with special thanks to J. Beigbeder, A. Murigneux, P. Carolo, S. Melkior for discussion / coordination*

Private partners from Amaizing project Caussade, Euralis, KWS, Limagrain, Maïsadour, Monsanto, RAGT, Syngenta, Biogemma, GEVES, Arvalis, *with special thanks to P. Flament, A. Gaillard J. Loregou and S. Praud for discussion / coordination*

Funding agencies: ANR, France AgriMer

