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Poplar genomics, genetics and breeding at INRA Orléans

Véronique Jorge

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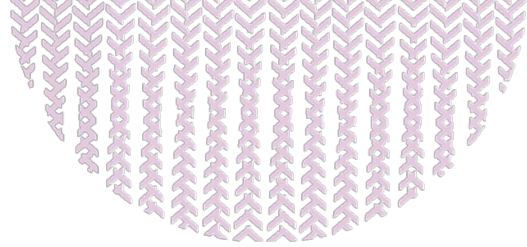
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Poplar genomics, genetics and breeding at INRA Orléans

V. Jorge

&

Contributors

INRA Units: AGPF, URGV, IaM, BIOGECO



University of Fribourg, April 5th 2007

ALIMENTATION
AGRICULTURE
ENVIRONNEMENT

INRA

Orléans Centre

Research on Forest Trees and Wood

Research Unit *Breeding, Genetics and Physiology of Forest Trees*

22 scientists
6 technicians, 3
administratives
4 graduate student

Associated Laboratory : ONF-INRA *Genetic Resources Conservation of Forest Trees*

2 scientists, 3 technicians

Research Unit *Forest Zoology*

10 scientists
7 technicians, 1
administrative
2 graduate students

Experimental Unit

2 engineers
17 technicians (6 technical teams)



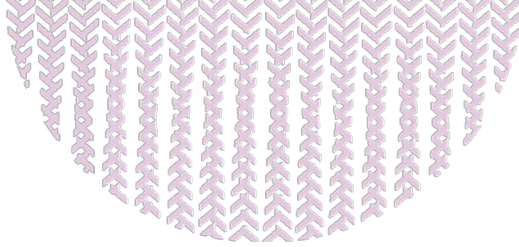
3 research teams

- >Genetics
- >Meristems
- >Xylem

Main Forest species studied :

Poplars, Douglas Fir, Pine, wild cherry, larix, walnut, ash tree





Poplars



Poplars

Genus *Populus*

6 sections and 35 (?) species



Populus nigra L.



Populus alba L.



Populus tremula L.



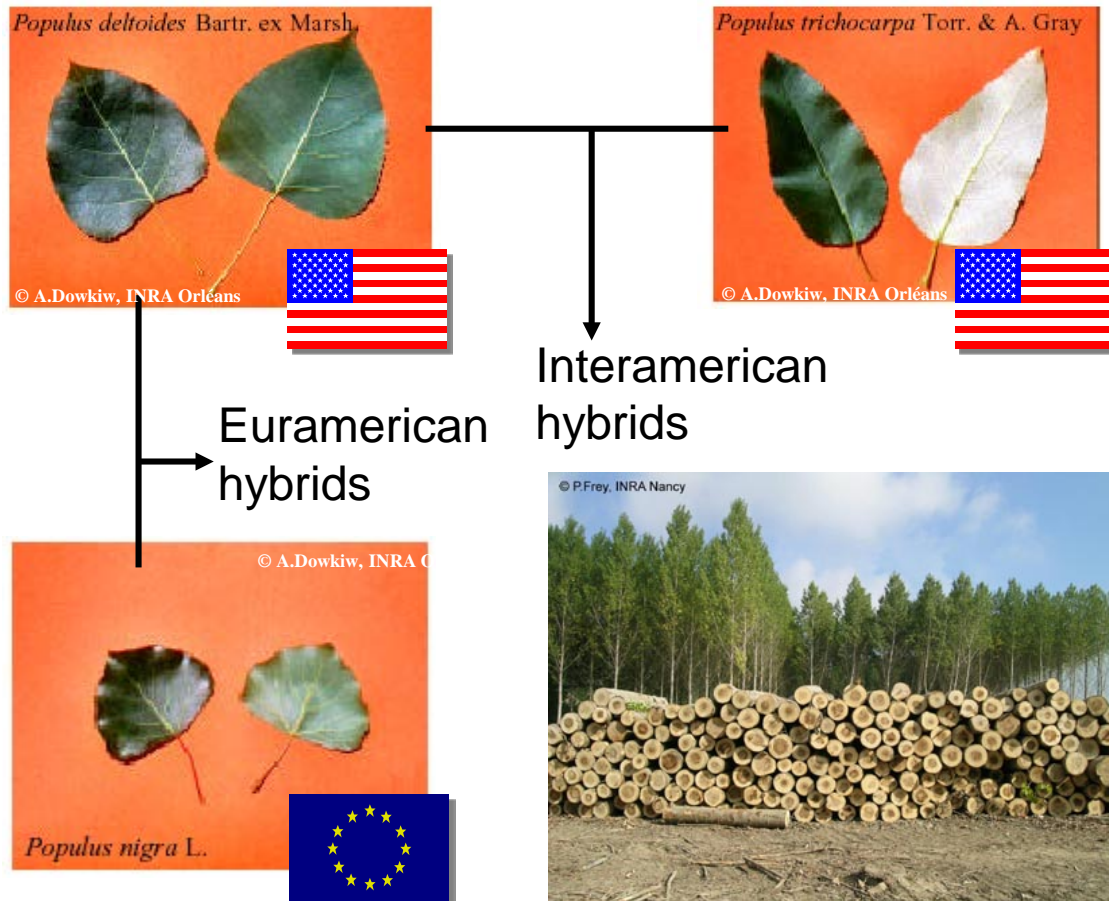
Populus trichocarpa Torr. & A. Gray



Populus deltoides Bartr. ex Marsh.

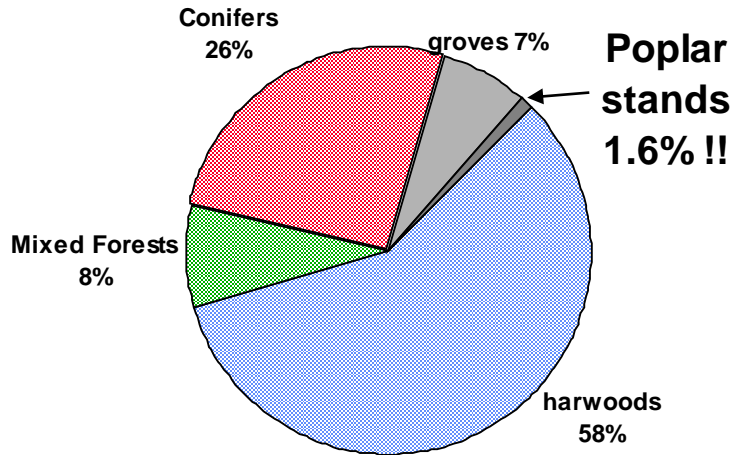
Poplars

Cultivated poplar are hybrids clones



Poplars

Poplar statistics in France



1.5 M m³ (2003)
= 230 000 ha



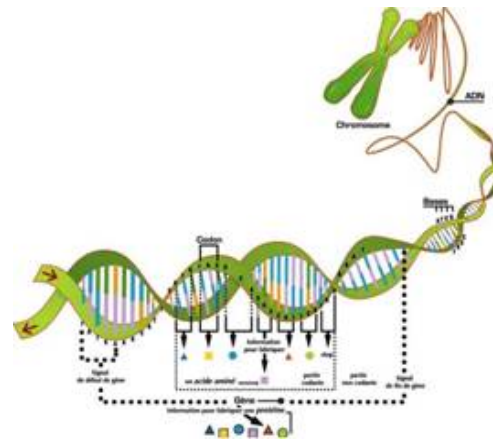
(Ministère de l'Agriculture
et de la Pêche, 2000)



Poplars

A model tree

- Fast growing
- Easy vegetative propagation (cuttings)
- Intra- and interspecific crosses
- Transformation
- Small genome



(G. Pilate et al, INRA Orléans)

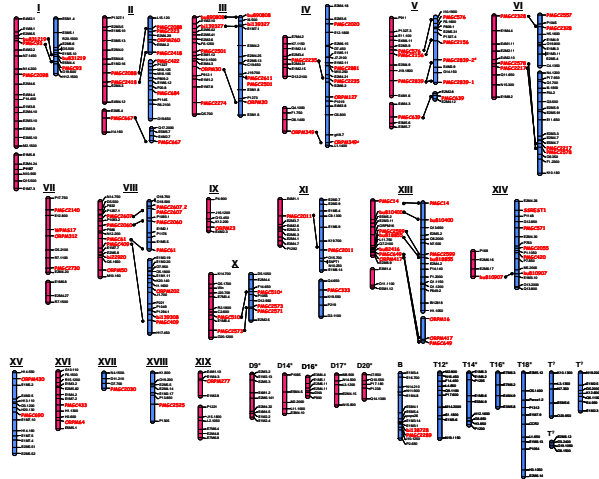


(M. Villar, INRA Orléans)

Poplars

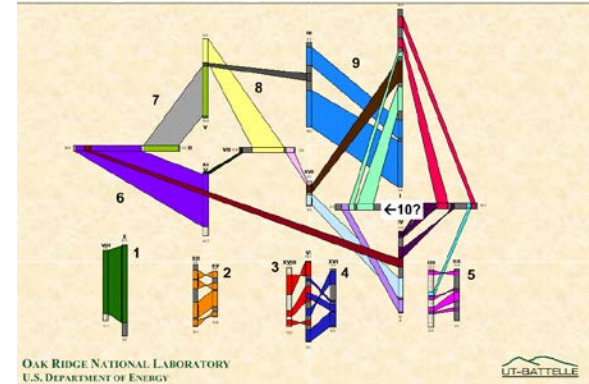
A model tree for genomics research

Genetic mapping



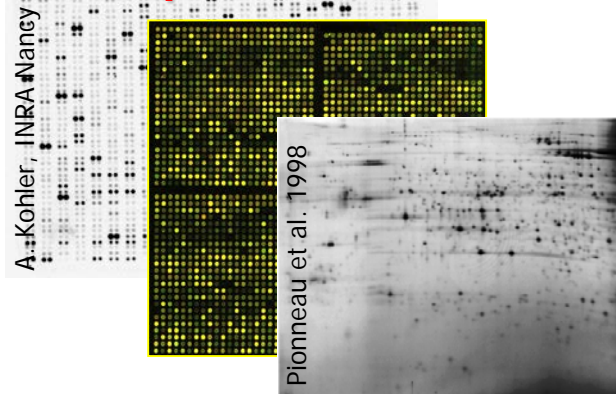
Genome sequence

P. trichocarpa Nisqually-1



Tuskan et al 2006

Transcriptomics, Proteomics, ...





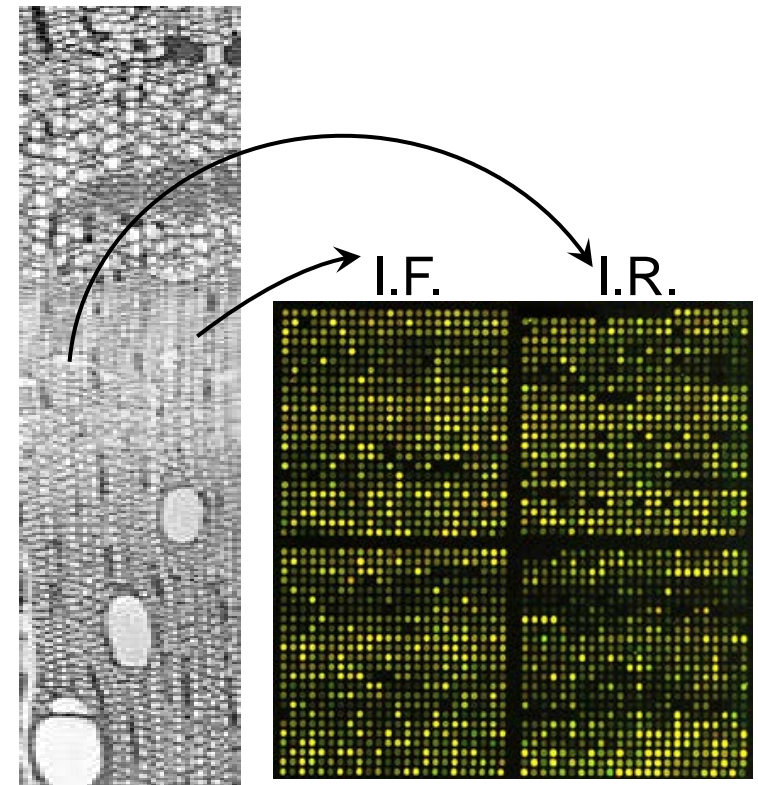
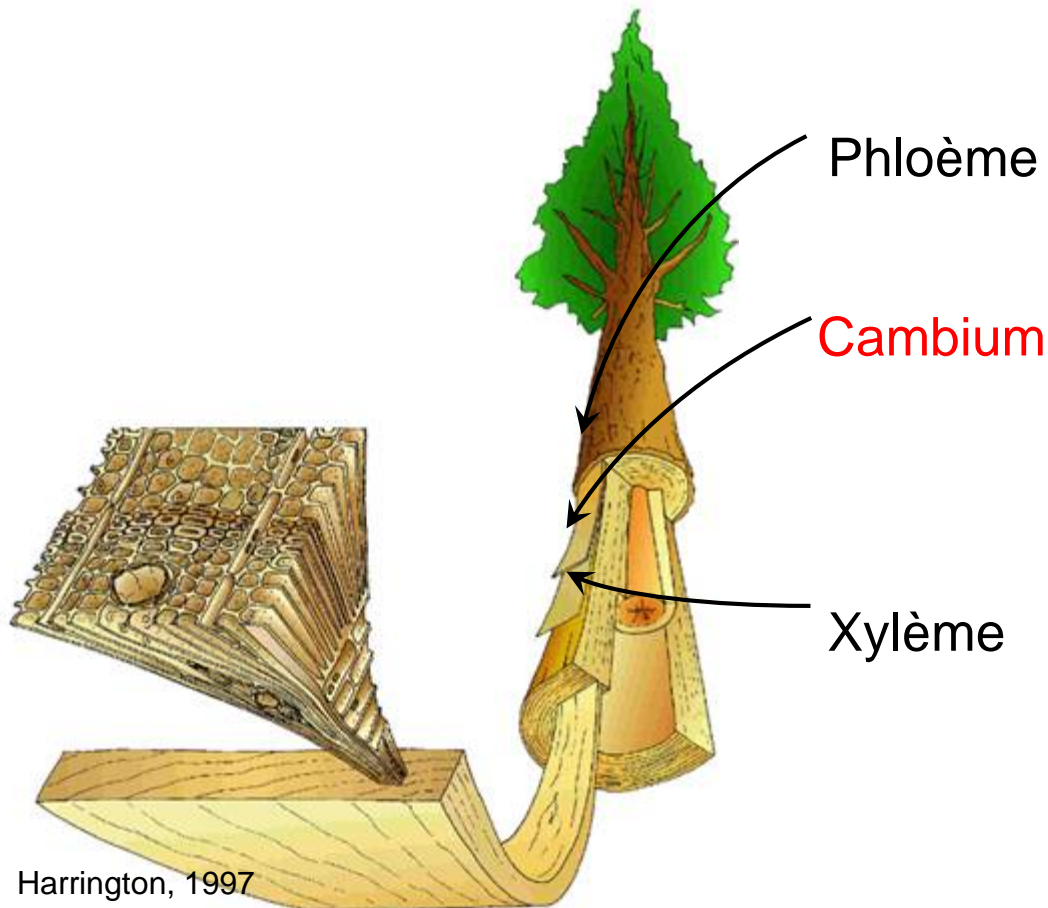
Three research themes



- 1- Identification of genes controlling traits of interest**
- 2- Breeding**
- 3- Conservation strategies, Management/Impacts of land use**

1- Identification of genes controlling traits of interest

Growth and wood quality



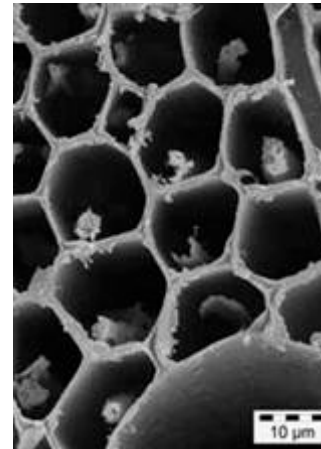
Goué *et al.* (2003)

1- Identification of genes controlling traits of interest

Tension wood

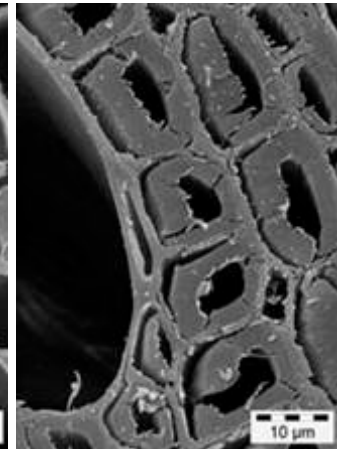


Normal wood



F. Laurans, INRA

Tension wood



F. Laurans, INRA

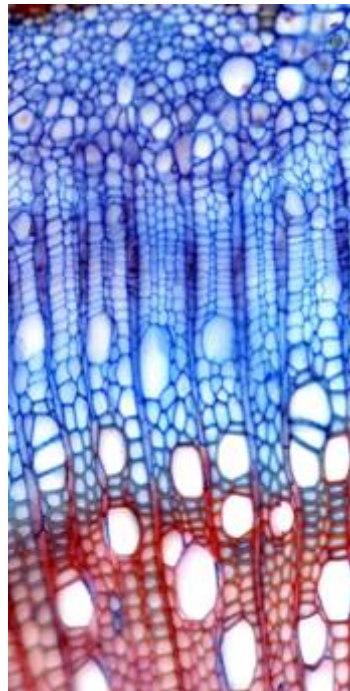
A model for wood formation
Easy experimental design
and rapid response

Biochemical, anatomic and
mechanical **differences**
=> modifications **gene expression**

1- Identification of genes controlling traits of interest

Tension wood

LIGNOME PROJECT 10 062 EST



CZ

JX

MX

mRNA

4 cDNA libraries :

young xylem in tension wood

young xylem in normal wood

Cambial zone

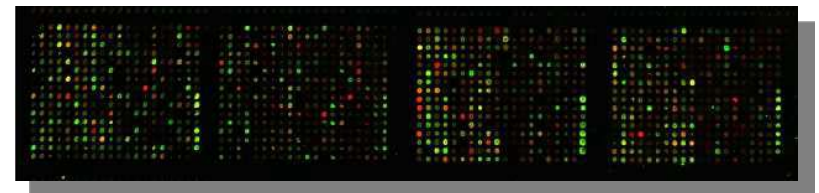
Mature xylem

Arabinogalactan protein-like
(AGPs) over expressed in tension
wood

Déjardin et al, 2004, Plant Biology

Lafarguette et al, 2004, New Phytologist

Unigene set 1400 sequences,
gene expression micro-arrays
(coll Univ. Limoges)



1- Identification of genes controlling traits of interest

Disease and pest resistance

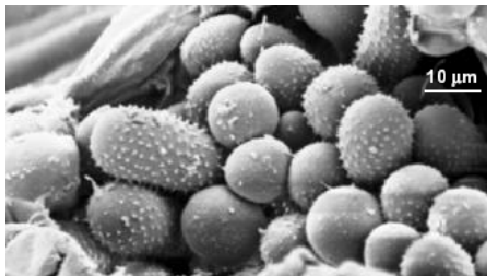


ADowkiw

C. Bastien



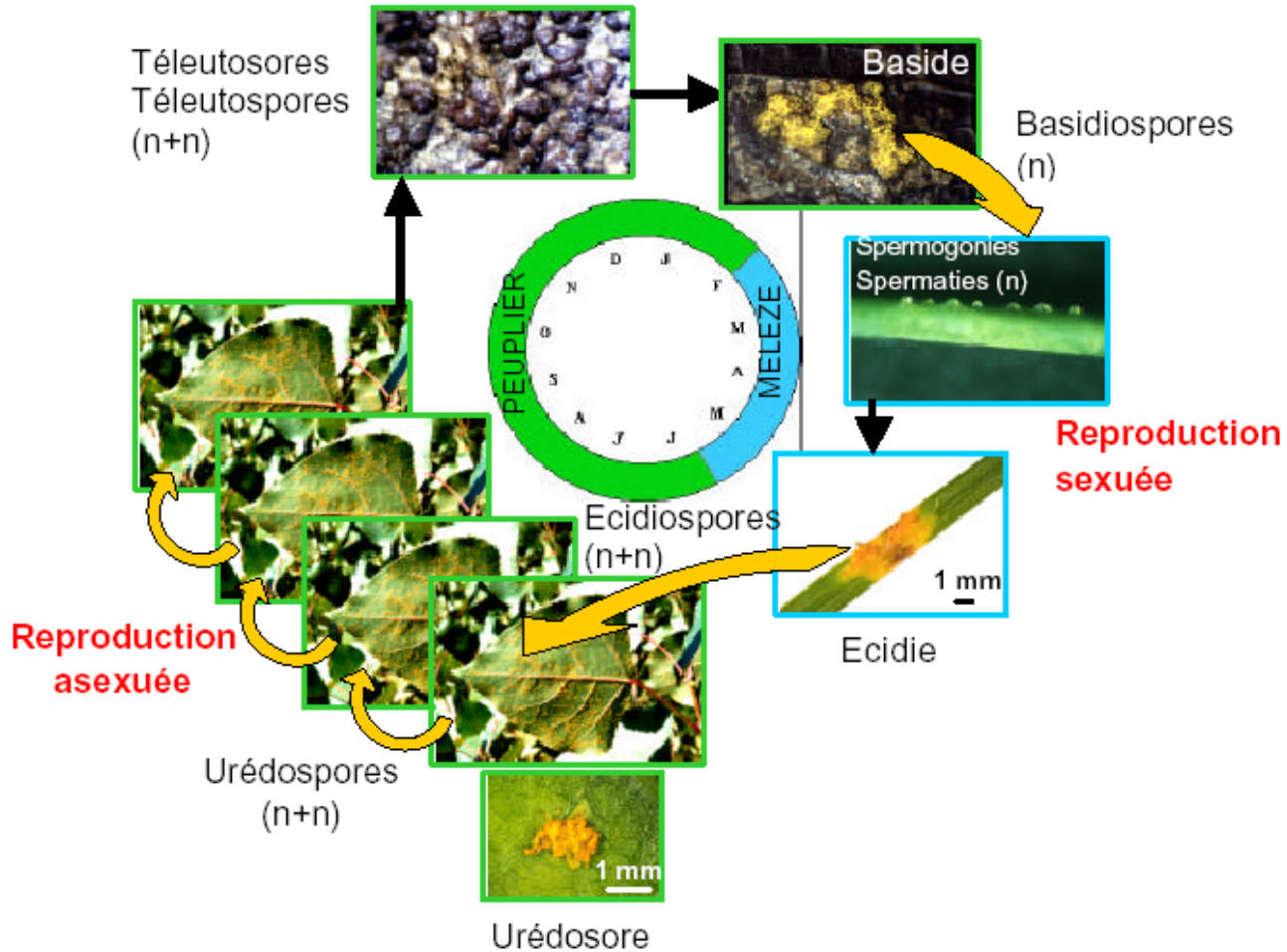
F. Laurans



1- Identification of genes controlling traits of interest

Rust

Melampsora larici-populina



1- Identification of genes controlling traits of interest

Evaluation of rust resistance

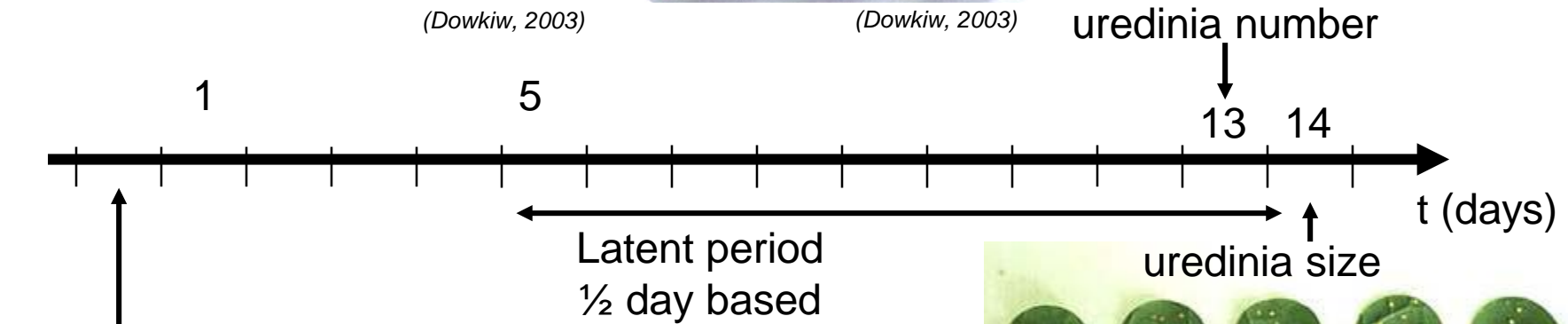
Laboratory



(Dowkiw, 2003)



(Dowkiw, 2003)

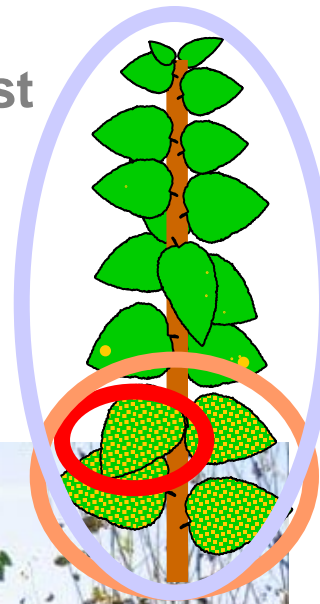


(Dowkiw, 2003)

1- Identification of genes controlling traits of interest

Evaluation of rust resistance

Field



1- Identification of genes controlling traits of interest

Evaluation of canker resistance

- > Nursery trials
- > Inoculation 1 year after plantation
- > Evaluation 1 & 2 years after inoculation



GI=1



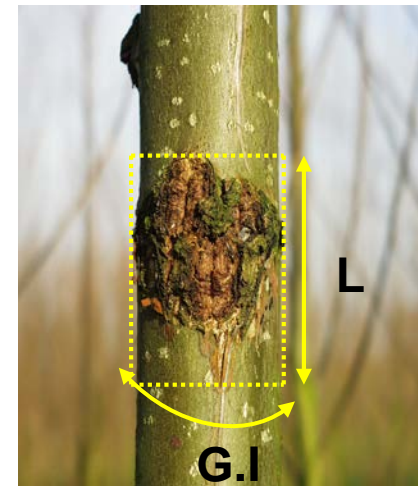
GI=2



GI=3



GI=4



1- Identification of genes controlling traits of interest

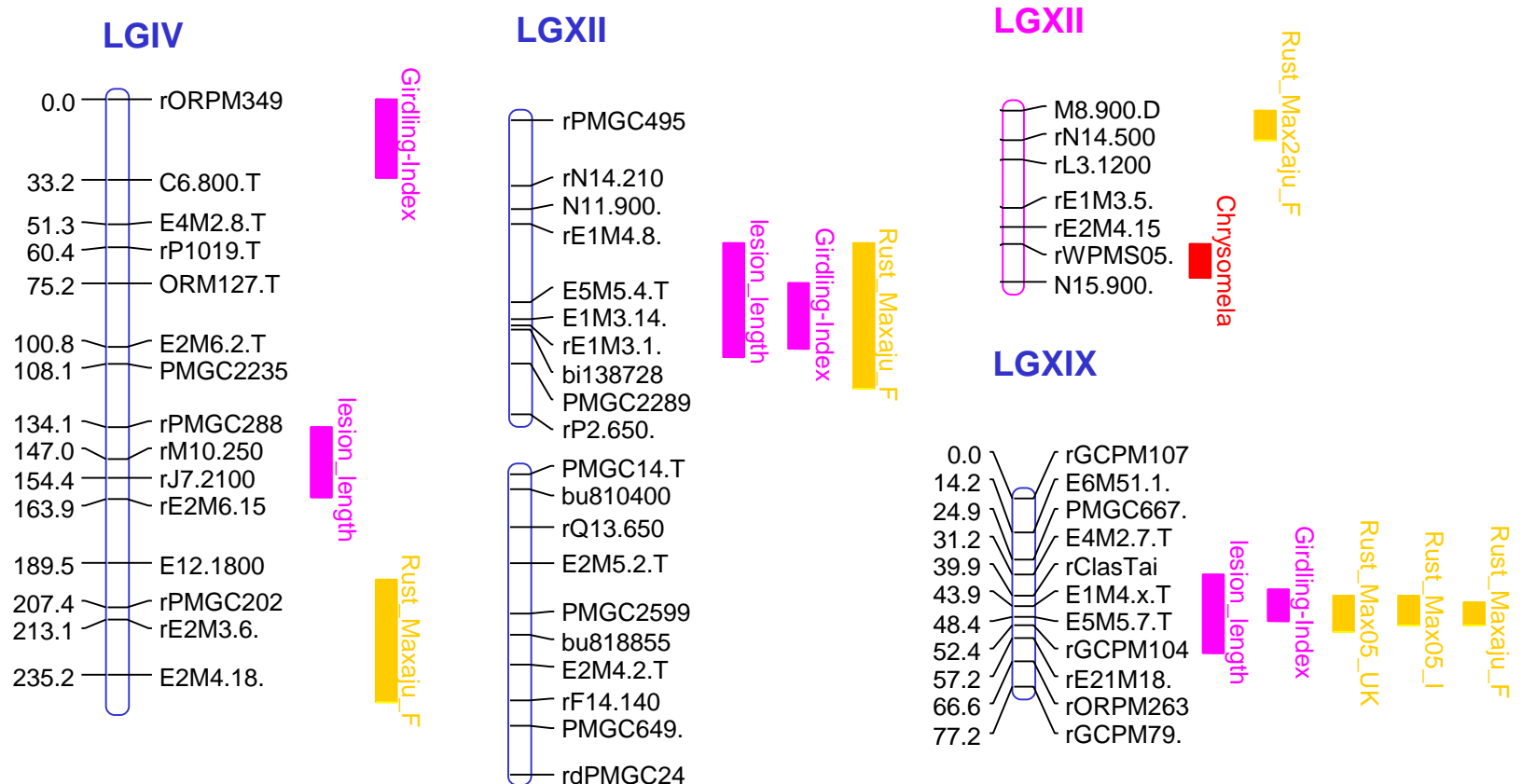
Evaluation of feeding preference of chrysomela

- Feeding multiple choice bioassay in laboratory conditions: boxes of 48 genotypes x 20 replicates
- Measurement of consumed leaf area



1- Identification of genes controlling traits of interest

Mapping QTLs for disease and pest resistance

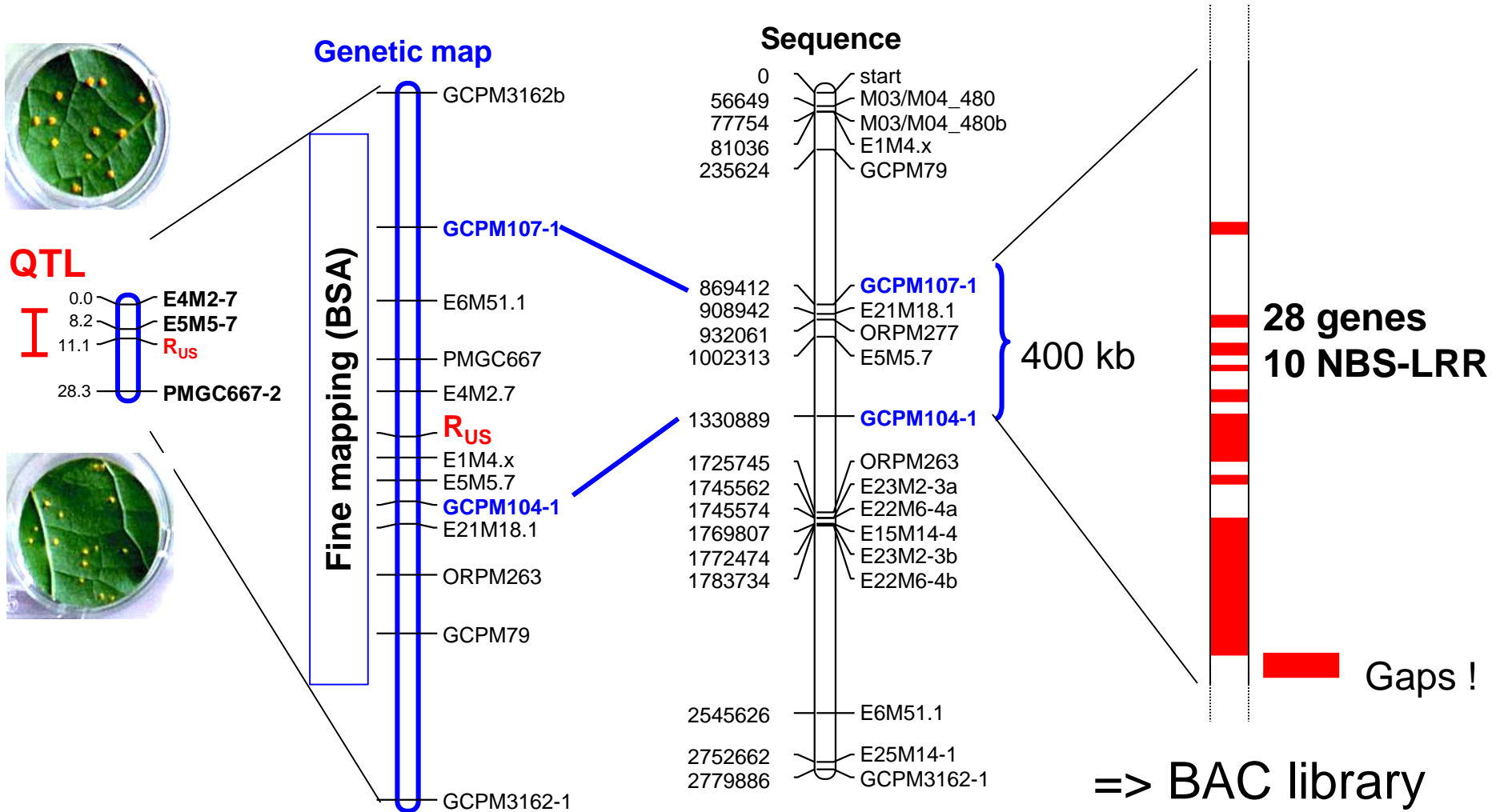


→ colocalization ? Analysis undergoing ...



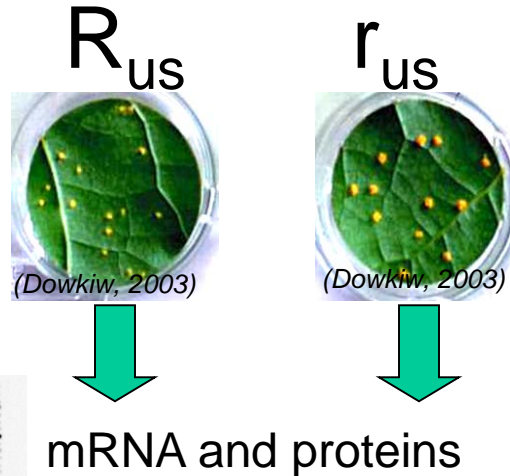
1- Identification of genes controlling traits of interest

Cloning genes controlling quantitative rust resistance

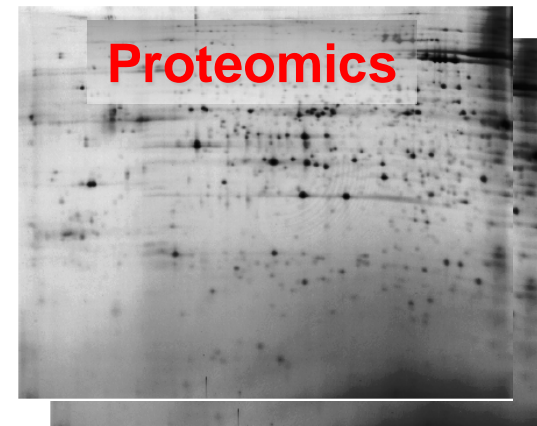


1- Identification of genes controlling traits of interest

Differential expression: bulks approach



High density filter (Kholer et al 2003)



2D Electrophoresis, Poplar xylem (Pionneau et al 1998)

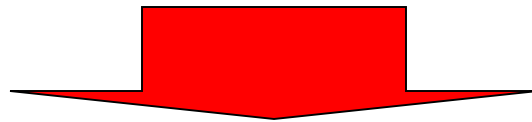
Collaborations IaM INRA Nancy, Francis Martin
Biogeco INRA Bordeaux, Christophe Plomion

1- Identification of genes controlling traits of interest

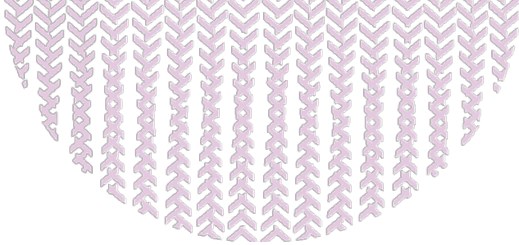
Outputs of mapping and genomic studies

« Informative » markers

- > Position on genome
- > Markers linked to QTL (partial, complete resistance, tolerance)
- > Candidate genes identified by genomic studies



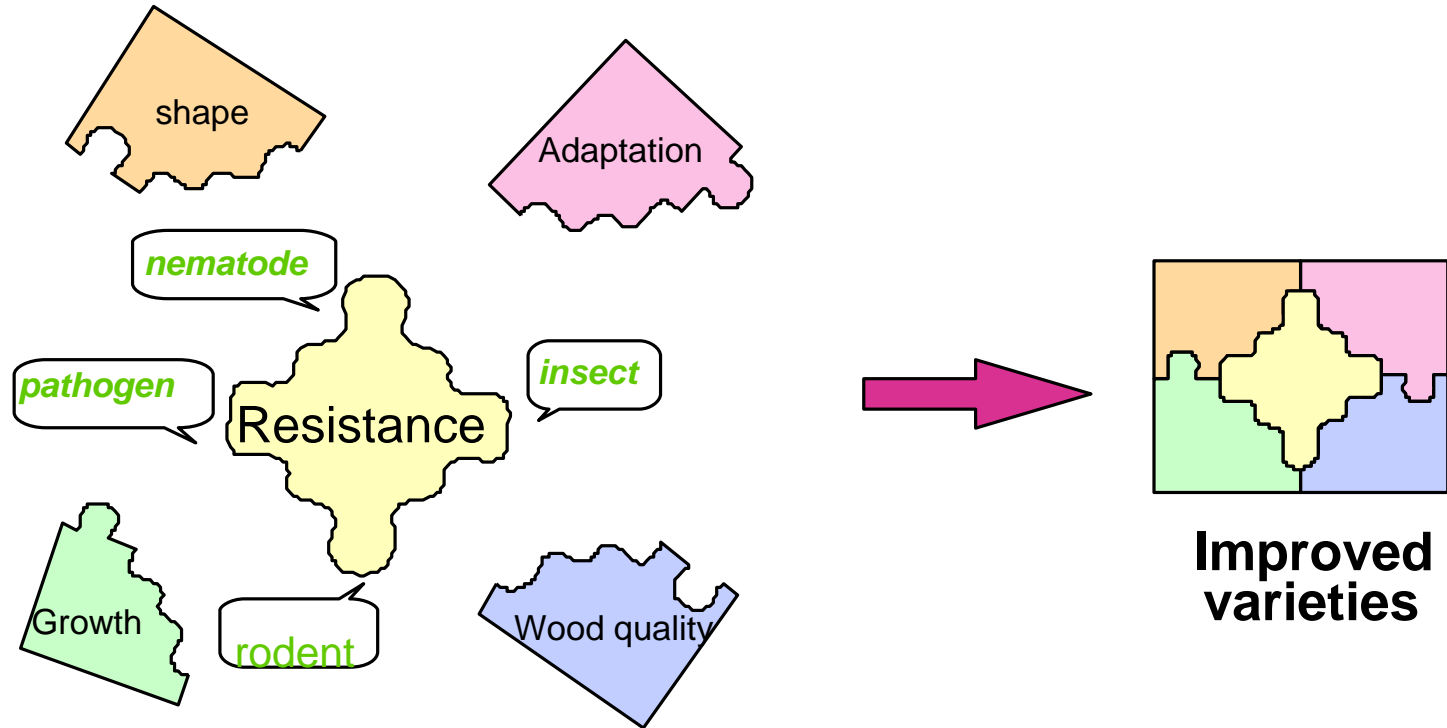
Marker Assisted Selection Diversity and association studies



2- Breeding



2- Breeding Goals

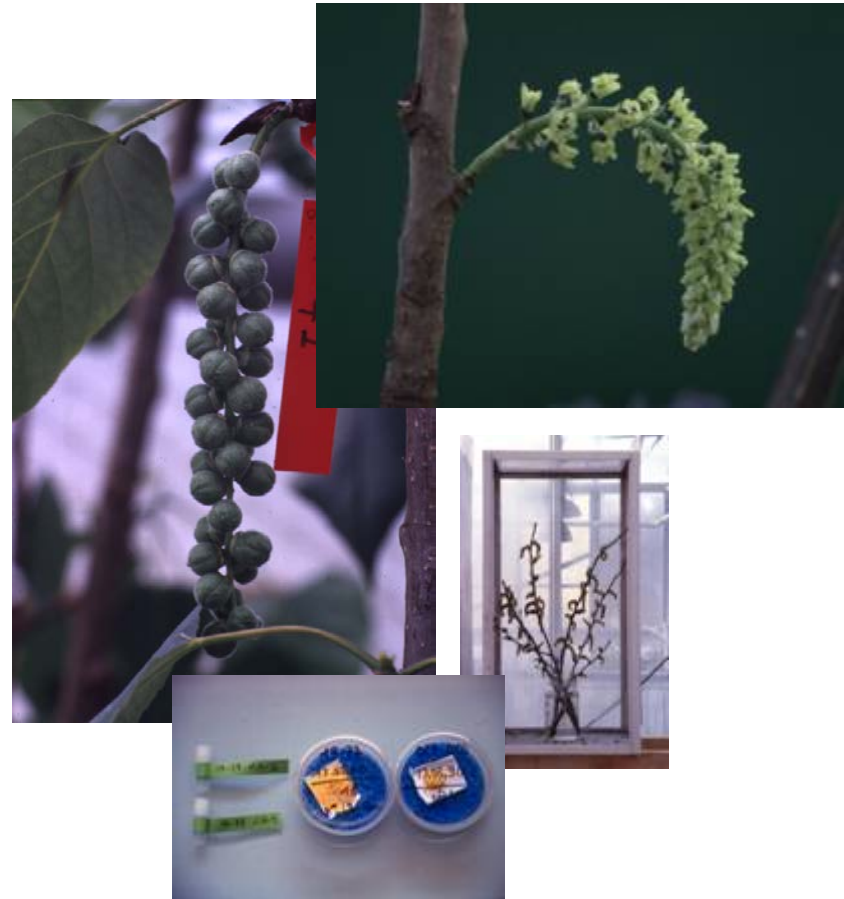


2- Breeding

Controlled hybridization

Factorial mating design

		<i>Populus trichocarpa</i>				<i>Populus deltoides</i>				
♀ \ ♂		36-100	19-73	19-77	101-74	73021	H200	L123	ALR	MSS
		(or)	(or)	(or)	(w)	(fl)	(ob)	(fl)	(fl)	(mss)
<i>Populus trichocarpa</i>	36-77	11 (39)	12 (40)	13 (40)	14 (40)	15 (02)	16 (25)	17 (15)	18 (01)	19 (03)
	(or)									
	36-134	21 (34)	22 (34)	23 (38)	24 (74)	25 (17)	26 (07)	27 (27)	28 (34)	29 (20)
	(or)									
<i>Populus deltoides</i>	212-161	31 (40)	32 (31)	33 (33)	34 (37)	35 (00)	36 (00)	37 (00)	38 (00)	39 (00)
	(or)									
	FPL	41 (36)	42 (40)	43 (37)	44 (38)	45 (00)	46 (18)	47 (02)	48 (07)	49 (08)
	(w)									
<i>Populus deltoides</i>	73028	51 (05)	52 (13)	53 (24)	54 (342)	55 (29)	56 (38)	57 (32)	58 (19)	59 (36)
	(fl)									
	L1500	61 (30)	62 (73)	63 (51)	64 (31)	65 (37)	66 (38)	67 (39)	68 (39)	69 (41)
	(fl)									
	L1230	71 (13)	72 (10)	73 (17)	74 (19)	75 (31)	76 (39)	77 (28)	78 (40)	79 (17)
	(fl)									
L1550	81 (44)	82 (00)	83 (31)	84 (90)	85 (40)	86 (40)	87 (40)	88 (40)	89 (40)	
(fl)										
TNS	91 (39)	92 (30)	93 (78)	94 (63)	95 (39)	96 (17)	97 (38)	98 (34)	99 (17)	
(tns)										



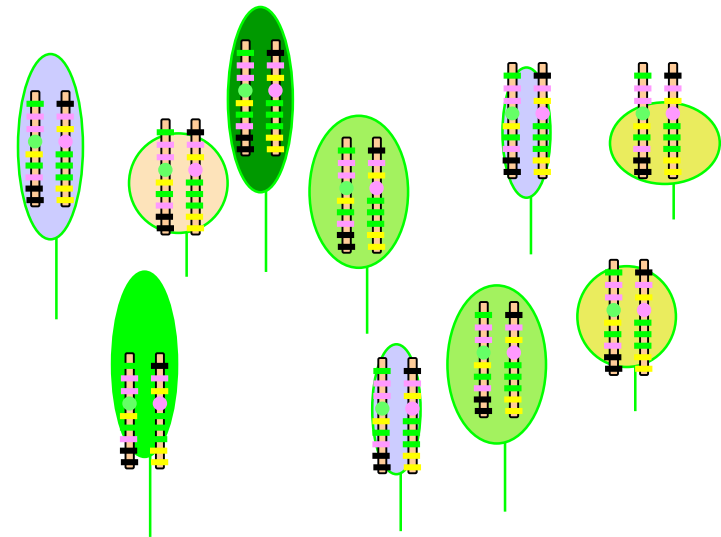
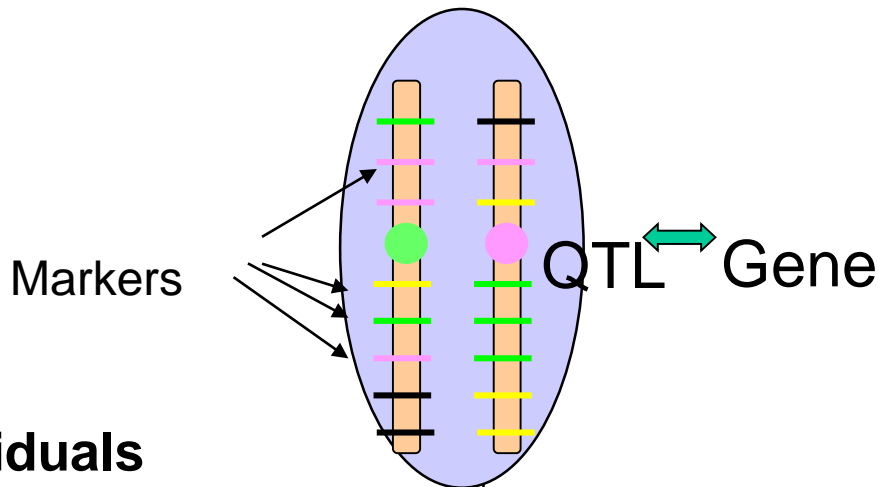
(M. Villar, INRA Orléans)

2- Breeding

Which Marker Assisted Selection for forest trees ?

Constraints and *problems* to resolve

- Generation Time
- Low linkage disequilibrium marker/QTL
- Low variability traits (wood properties ...)
- Transferability of markers
- *Consanguinity between varieties*
- *Low plasticity / adaptability ?*
- *Correlation between traits*



Individuals

Maintain heterozygosity level

Select / **Genes-markers**

Populations

Conservation of allelic **diversity**

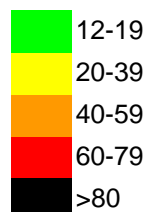
2- Breeding

Example of constraints: transferability of markers

Comparative mapping in genus *Populus*

		P. alba		P. deltoides			P. nigra			P. trichocarpa		Sequence P. trichocarpa
		Populus Alba 14P11 POP4	Populus Alba 6K3 POP4	Populus Deltoides D001 POP3	Populus Deltoides D002 POP3	Populus Deltoides POP2	Populus Nigra 58-861 (female) POP5	Populus Nigra POP3	Populus Nigra Poli (male) POP5	Populus Trichocarpa POP2	Populus Trichocarpa POP3	Populus trichocarpa Markers Mapped on Sequence
P. alba	Populus Alba 14P11 POP4											62
	Populus Alba 6K3 POP4	45										51
P. deltoides	Populus Deltoides D001 POP3	17	16									43
	Populus Deltoides D002 POP3	19	13	269								41
	Populus Deltoides POP2	17	14	27	29							44
P. nigra	Populus Nigra 58-861 (female) POP5	29	25	21	23	23						68
	Populus Nigra POP3	13	12	27	23	15	18					32
	Populus Nigra Poli (male) POP5	34	26	25	29	28	69	23				79
P. trichocarpa	Populus Trichocarpa POP2	15	13	29	28	35	16	16	22			54
	Populus Trichocarpa POP3	16	13	29	31	21	20	16	24	26		52
P. trichocarpa x P. deltoides	Populus Trichocarpa x Populus Deltoides hybrid	17	20	26	23	33	29	14	34	31	15	75

Number of correspondences





3- Conservation strategies, Management/Impacts of land use



3- Conservation strategies, Management/Impacts of land use

Populus nigra : an endangered species

- > Agriculture
- > Confinement of rivers, dams regulation (no flood)...
- > gene flow from cultivated poplars



Loire à Orléans



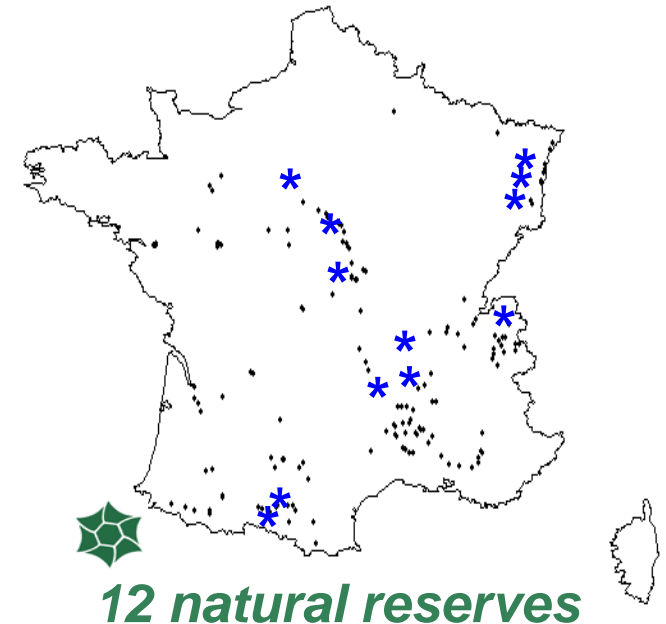
Barrage de Villerest au sud de Roanne



© P.Frey, INRA Nancy

Populus nigra : conservation strategies

- > *Ex situ* collection (309 ind.)
- > *In situ* Conservatories



Evaluation and comparison of diversity at
phenotypic and molecular levels

3- Conservation strategies, Management/Impacts of land use

Wild gene pool
Populus nigra



INTERPOPPER project

Interactions between gene pools

Riparian forest



Cultivated gene pool

P. deltoides X *P. nigra*
P. deltoides
P. deltoides X *P. trichocarpa*



Pollen

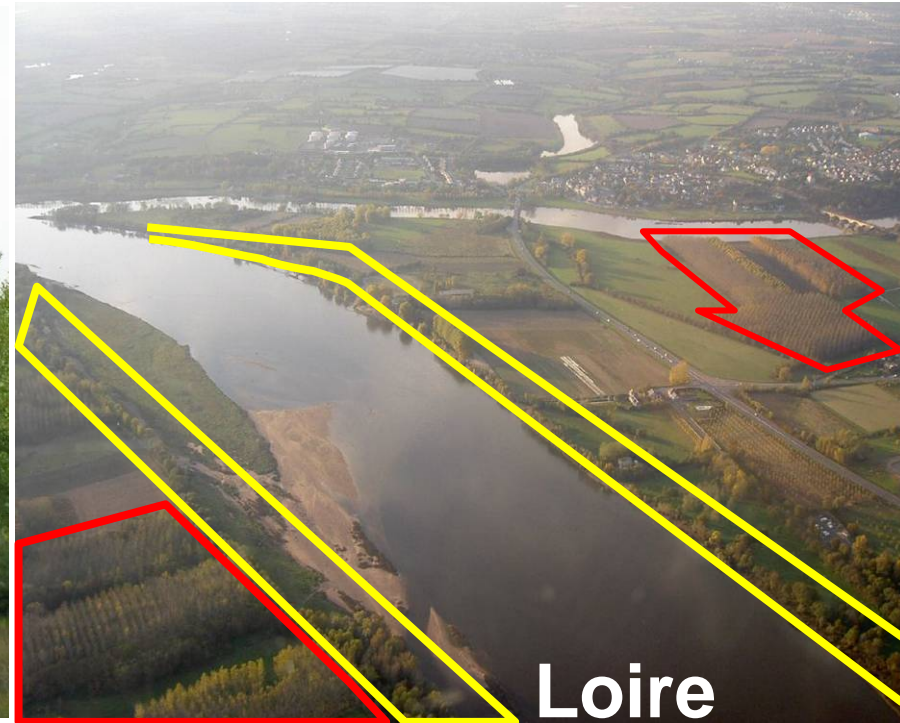
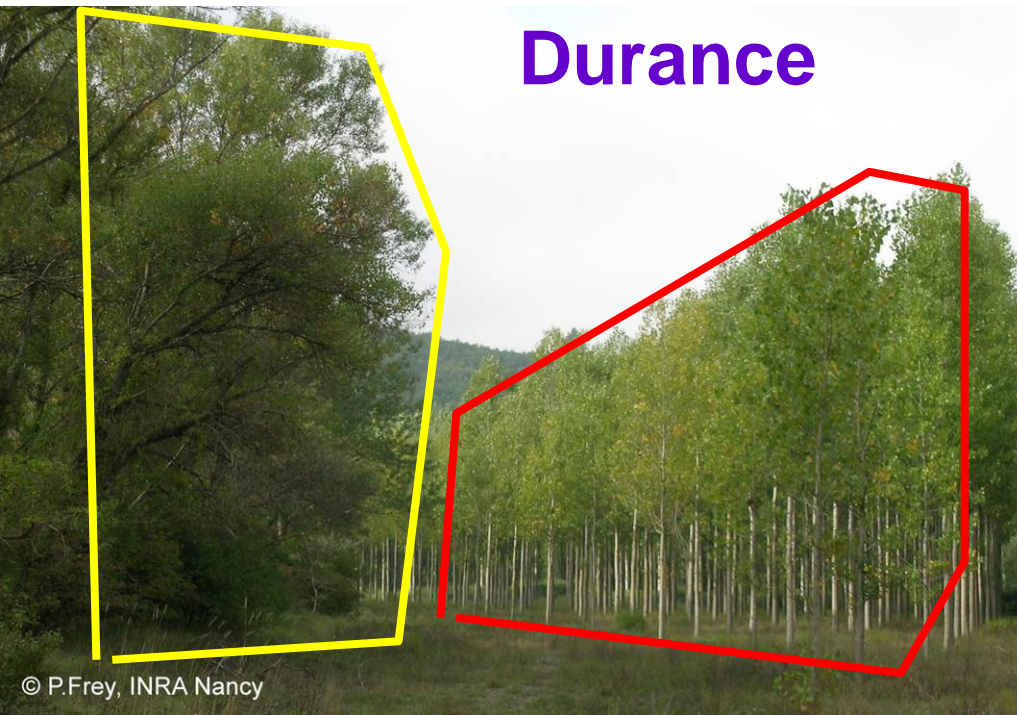
Pollen seeds

Ornamental gene pool
Populus nigra cv *Italica*



3- Conservation strategies, Management/Impacts of land use

Gene flow Cultivated <-> Natural



3- Conservation strategies, Management/Impacts of land use

Gene flow Ornamental <-> Natural

Lombardy poplar



P.nigra var. *Italica* Duroi

A unique genotype from *P. nigra* L. species
(« *Italica* », « San Giorgio »)

Male, flowerfull

Planted everywhere in the landscape in
alignment or isolated

Since very long time in Europe (1750)



➤ 20 individuals from the French ex situ collection
(6,5%) are **F1** hybrides with « **Italica** » (Jorge, 2005)

3- Conservation strategies, Management/Impacts of land use

Pathogen flow



High level epidemics
Strong selection
Complex races (numerous virulences)

Low level epidemics
Coevolution
Simple races

3- Conservation strategies, Management/Impacts of land use

INTERPOGGER project

- (i) To identify molecular determinants of the poplar/*Mlp* interaction and developing pertinent markers;
- (ii) To quantify gene flow from cultivated to wild poplars using neutral and adaptive markers;
- (iii) To identify biological and physical factors conditioning gene flow success through modelling gene flow using spatial information;
- (iv) To evaluate the evolutionary impact of gene flow on poplar/*Mlp* interactions.

3- Conservation strategies, Management/Impacts of land use

One study site

Saint Ay - Loire river

▪ Area :

11, 5 ha

▪ Dimensions :

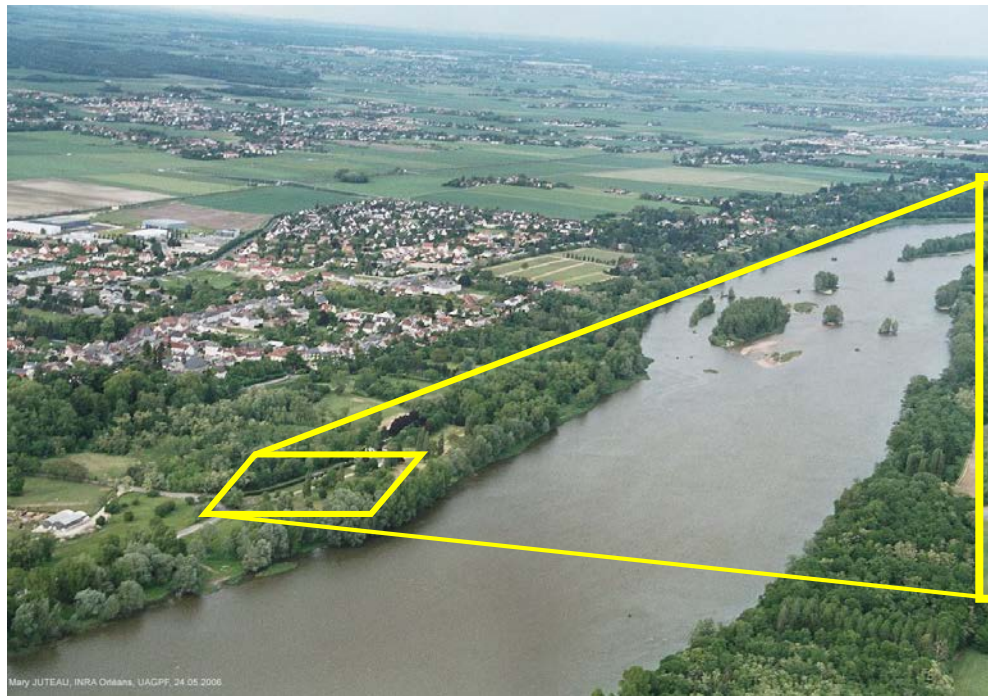
1225 m x 180 m

255 *P. nigra*
males

13 *P. nigra* var.

Italica

229 *P. nigra*
females



Thanks to

INRA Orléans
UAGPF

Catherine BASTIEN
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Arnaud DOWKIW
Vanina GUERIN
Jean-Philippe MASLE
Marie JUTEAU
Gilles PILATE
Françoise LAURANS
Philippe LABEL
...

INRA Evry
URGV

Patricia FAIVRE-RAMPANT
Alois BRESSON

INRA Nancy
IaM

Francis MARTIN
Jean PINON
Pascal FREY
Sébastien DUPLESSIS
Anegret KOHLER
Cécile RINALDI

INRA Bordeaux
BIOGECO

Christophe PLOMION



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Thank you

PHILADELPHIA MUSEUM OF ART



MONET



University of Fribourg, April 5th 2007

ALIMENTATION
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INRA