Pest and pathogen resistance in peach

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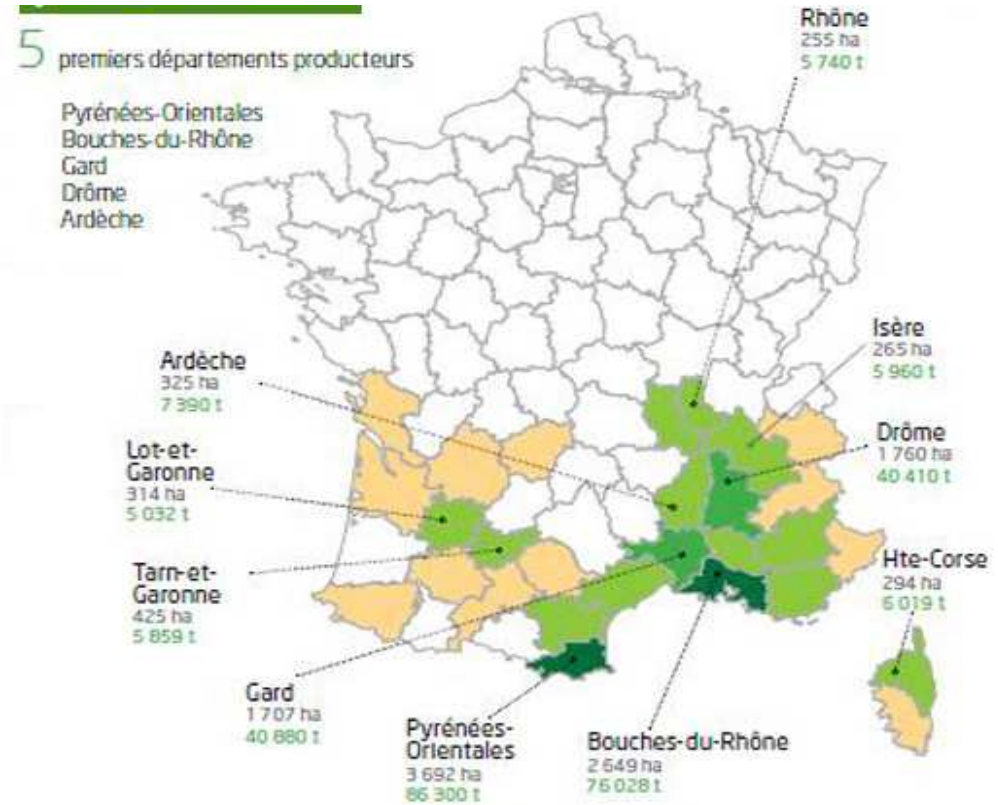
Socio-economic context

- Europe is the 2nd producer of peaches, nectarines and Pavies after Asia
  - ➢ 4,17 millions tons in 2016 (21 millions tons world-wide)
- The main four European producers are Italy (1,6 millions tons), Spain (1,1 millions tons), Greece (848,000 tons) and France (214 000 tons)
- Peach is the 2nd fruit production in France (after apple)

➢ Mainly cultivated in the South-East

➢ 90% for fresh market

➢ French market is the main output



Socio-economic context

Peach is affected by numerous diseases and pests

- Powdery mildew (*Podosphera pannosa* var *persicae*)
- Leaf curl (*Taphrina deformans*)
- Brown rot (*Moninilia* spp.)
- Bacterial spot *(Xanthomonas arboricola* pv *prunii*)
- Sharka (Plum pox virus)
- Green peach aphid (*Myzus persicae*)
- R-K nematodes (*Meloidogyne spp.)…..*
- And several minor ones……

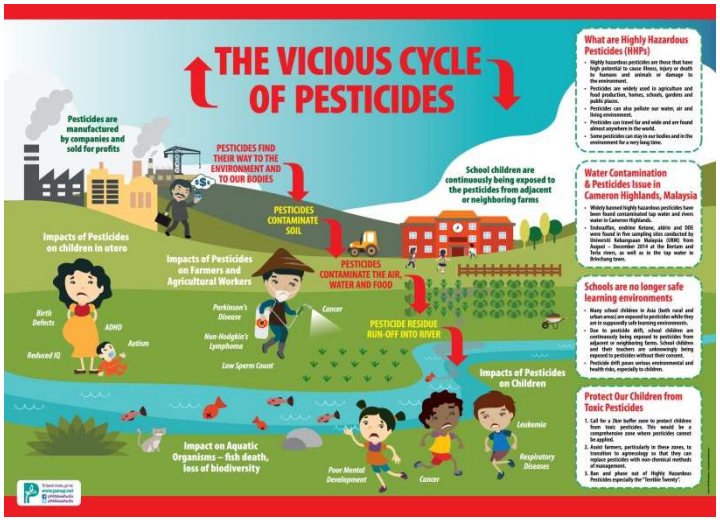
Socio-economic context

Prophylaxis is not sufficiently efficient

- Chemicals are widely used throughout the year for phyto-sanitary protection
  - 1% of the cultivated surface for the fruit orchards
  - 21% of the insecticide market
  - up to 24 treatments/year

Main consequences

- Environmental issues (contamination of soils and water, loss of biodiversity..)
- Health concern for fruit growers (sprays) and consumers (chemical residues)
- Development of resistances to pesticides (Ex: Imidacloprid for aphids)
- High financial and social cost



Socio-economic context

How have these issues been addressed?

Responses of the society

- More restrictive standards and stronger limitations of the use of chemicals and pesticides in the European community
  - ➢ 250 active phyto-sanitary substances forbidden in Europe to date
- Increase of the consumer pressure for sustainable environment-friendly fruit production

Responses of peach growers

- General trend to reduce synthetic pesticides and fertilizers
- Development of integrative cultural practices and alternative phyto-protection to limit their use
- Slow but continuous development of Organic farming

Response of researchers

- Researches aimed at developing **resistant cultivars** with good agronomical features for long-term sustainable sanitary protection

Resistance to pests and diseases

A promising option

- Genetic control based on sources of resistance is natural and safe
- Does not impact environment negatively
- Could insure long-term sustainable sanitary protection of the orchards

However

- Need for sources of resistance covering a broad range of pests and pathogens
  - ➢ systematic phenotyping of peach collections would allow uncovering new sources of resistance
- Not or little taken into account by commercial breeders to date

➢ Need to be addressed by public Institutes

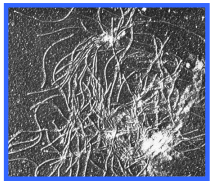
Peach breeding programs at INRA-UGAFL
Two main targets closely linked

Resistance to pests and diseases

Leaf curl

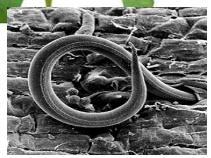
Brown rot

Sharka



Green peach aphid

Nematodes



Fruit Quality

Our primary objective: improving resistance in peach

Short term: multi biotic-stress resistance

- identifying new genitors, sources of resistance or resilience
- combining several strong monogenic resistance factors in improved cultivars
- testing resistance durability in multi-site orchards and low-input conditions

Long term : sustainable resistance

- by combining monogenic (Mendelian) and polygenic quantitative resistance factors to prevent resistance to be overcome, thanks to molecular markers

Main targets to meet challenges

- Aphids, powdery mildew, bacterial spot, leaf curl, brown rot, *sharka*
- root-knot nematodes (root-stocks)

in conditions of low-input management

Plant material

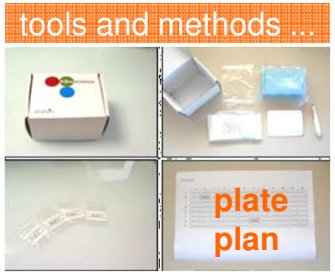
- bi-parental progenies
- populations segregating for multi-traits interdependent populations
- multi-parental populations
- core-collections

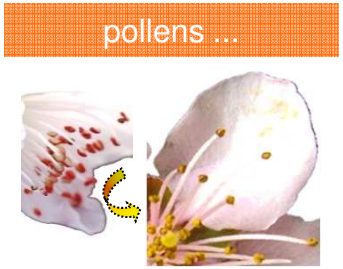
Our secondary objective

Support the French community of peach breeders

- Contribute to the development of new methods for a sustainable, environment-friendly, peach orchard

  - **by repositioning our team upstream** of the peach breeding programs
    - ➢ on objectives not/little taken into account by the others stakeholders
  - **by transfering to breeders know-how**, tools and improved material for the further development of full varietal ranges
    - ➢ pre-breeding/elite material
    - ➢ molecular marker linked to resistance characters
    - ➢ DNA-informed methods for seedling selection





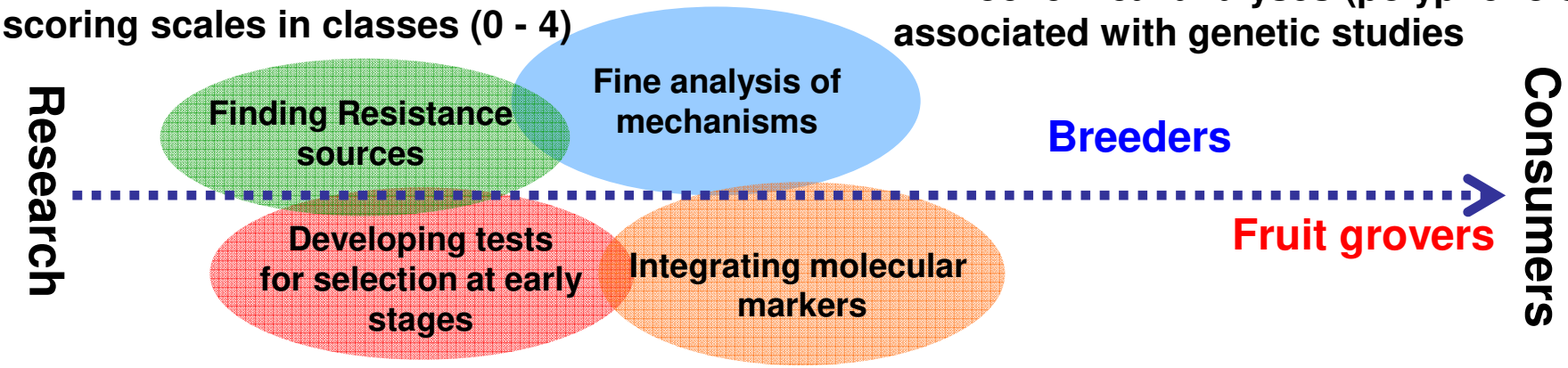
A pluridisciplinary approach for improving resistance
> genetic to functionnal

Evaluation of collections and genetic resources

- Resistance scoring
- Classic biological tests
- On leaves and/or fruits
- Inoculations / controlled infestations
- scoring scales in classes (0 - 4)

Examples:

- Study of the aphid feeding behaviour by electropenetrography (EPG)
- Analysis of the organic volatile compounds
- Biochemical analyses (polyphenols) associated with genetic studies



- Tests performed at a young stage in greenhouse
- Validation under insect-proof tunnel
- And in orchard at a grown-up stage

- Genotyping and mapping of segregating populations
- QTL and candidate gene mapping
- Marker assisted Breeding (MAB)

A few sources of resistance available for breeding

Mostly found in the pool of genetic diversity available in the collections

- Wild species related or close to peach
- Rootstocks
- Ornementals
- Processing peaches
- Old cultivars

***Prunus davidiana* (clone P 1908) : wild species related to peach**
resistant to powdery mildew, green peach aphid leaf curl and PPV
… but the agronomical level is very low

'Pamirskij 5' and 'Rubira' rootstock peaches
resistant to powdery mildew and green peach aphid respectively

'Del Cid' and 'Texas' almond
resistant to sharka and powdery mildew respectively

Characteristics of the sources of resistance used at UGAFL

Prunus persica

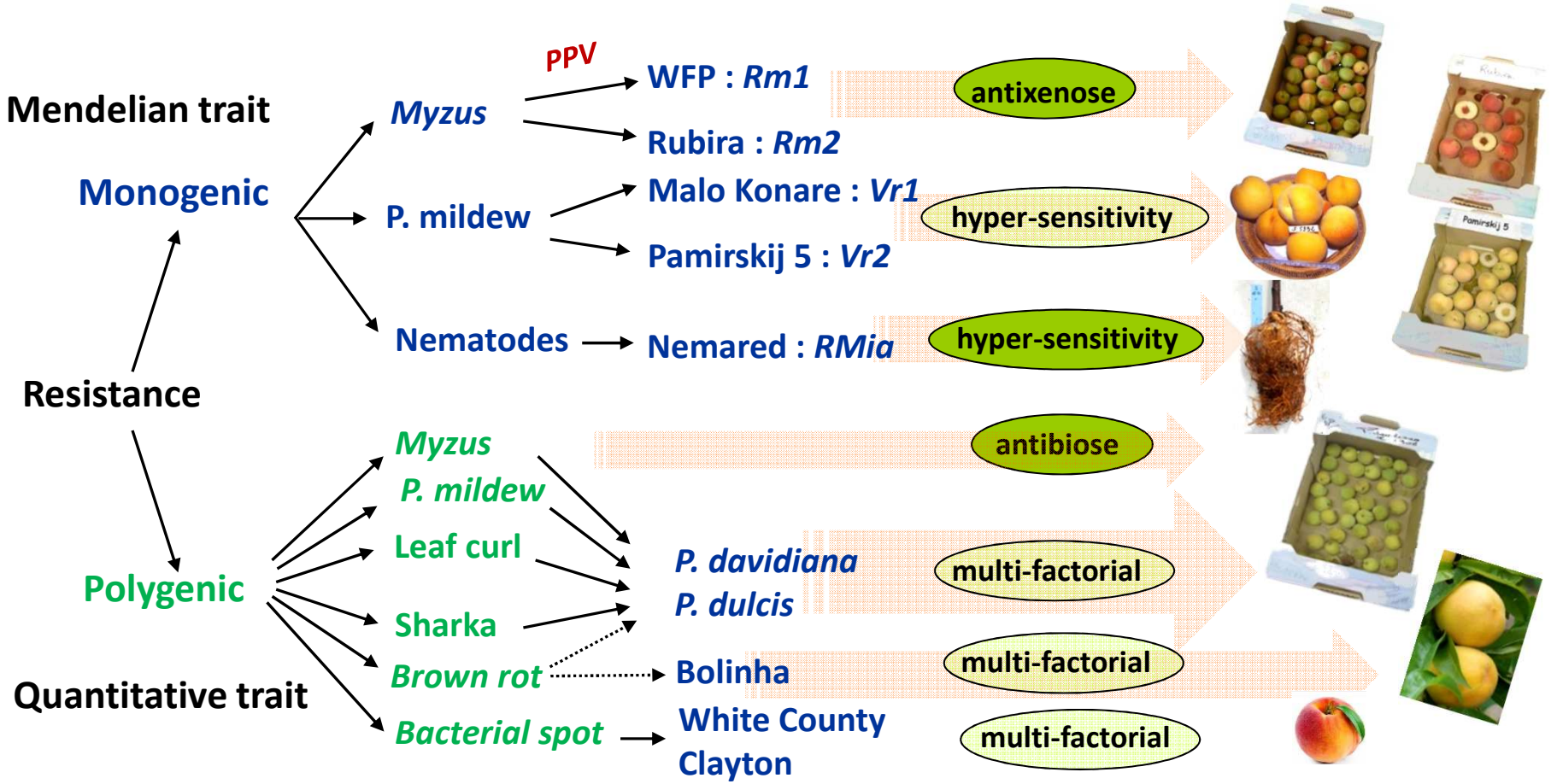
	Origin	Feature
Green peach aphid		
▪ Summergrand	USA	yellow-flesh nectarine
▪ Rubira	France	rootstock
▪ Weeping Flower Peach	USA	ornemental
Powdery mildew		
▪ Malo Konare	Bulgaria	canning peach
▪ Pamirskij 5	Ukraine	rootstock
Bacterial spot		
▪ White County	USA	white-flesh peach
▪ Clayton	USA	yellow-flesh peach
Brown rot		
▪ Bolinha	Brazil	canning peach
Nematodes		
▪ Nemared	USA	rootstock

Prunus davidiana

Green peach aphid, Powdery mildew, Leaf curl, Sharka….

▪ clone P1908	China	wild species (rootstock)

Type of resistance, targets, sources of resistance, mecanisms involved



Innovative approach : multi-traits target and use of species close to *P. persica*

Sources of resistance available
But…the agronomic level is low

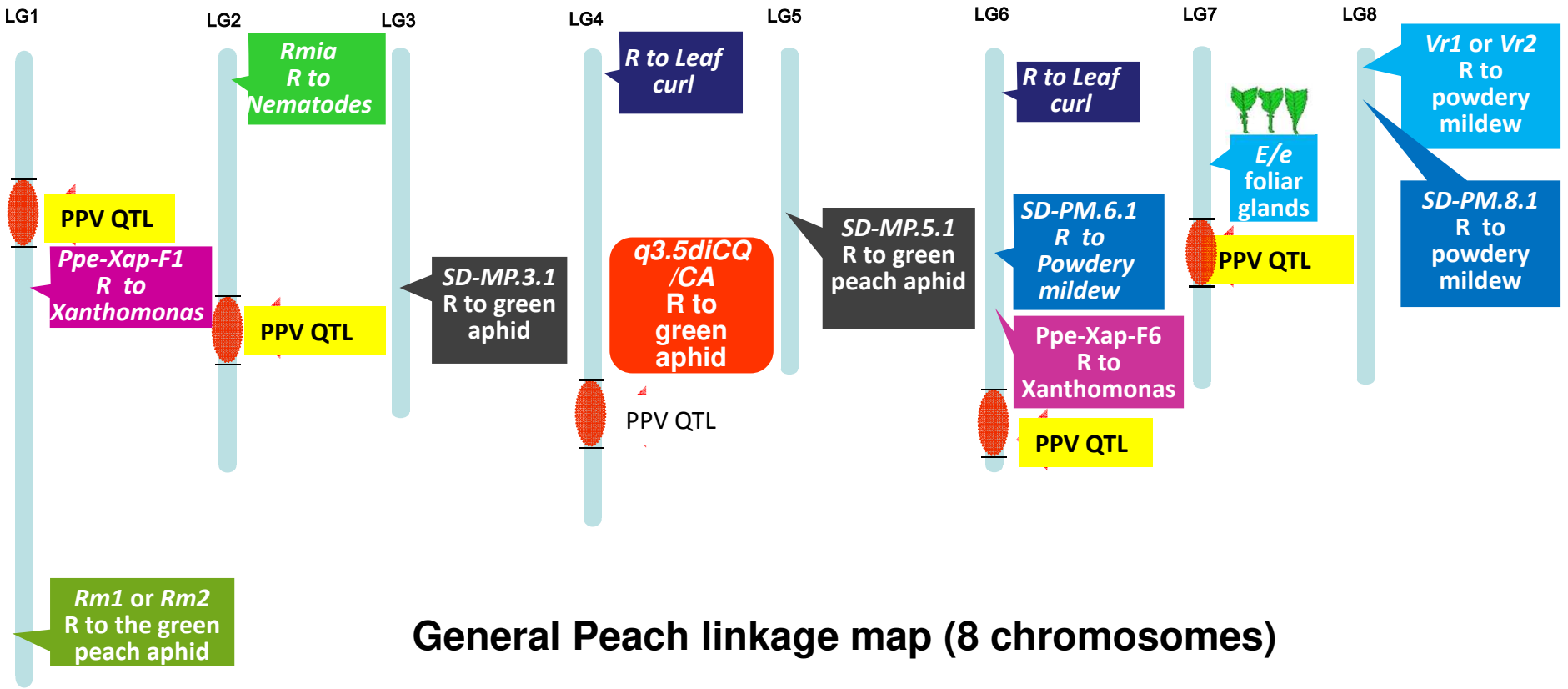
Need agronomic improvement

- Successive crosses with accessions having good characteristics are needed to get commercial agronomic value of the fruits
- Traditional breeding process is slow and time consuming due to the length of juvenile stage
    - Ten to fifteen years necessary to select individuals with good potential
- Molecular markers linked to resistance loci could help boosting the release of novel resistant varieties

Implementation of Marker assisted seedling selection (MASS)

DNA-informed selection of resistant peach seedlings at each step of the breeding process

Regions of the peach genome involved in resistance and used for developing DNA-informed breeding



General Peach linkage map (8 chromosomes)

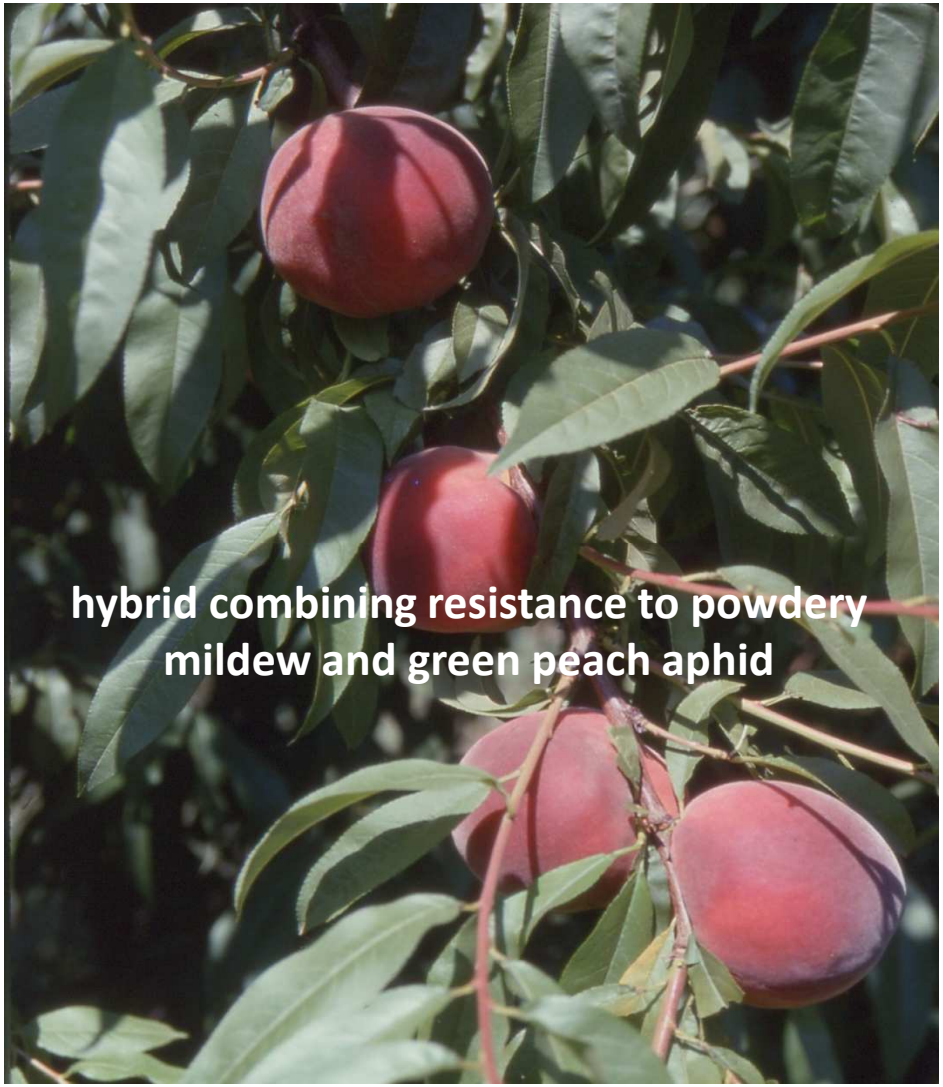
DNA-informed breeding

- **Application to monogenic resistance: Powdery mildew + *Myzus persicae***

Selection of individuals combining resistance to powdery mildew from 'Malokonare' and resistance to *Myzus* from 'Weeping flower peach' using molecular markers associated with each of the trait

Satisfactory association between the resistance phenotype and the alleles linked to resistance

One more generation to get commercial agronomic value



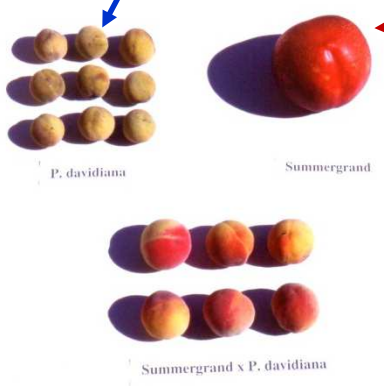
DNA-informed breeding

Application to quantitative resistance: Sharka, Myzus, Powdery mildew, Leaf curl

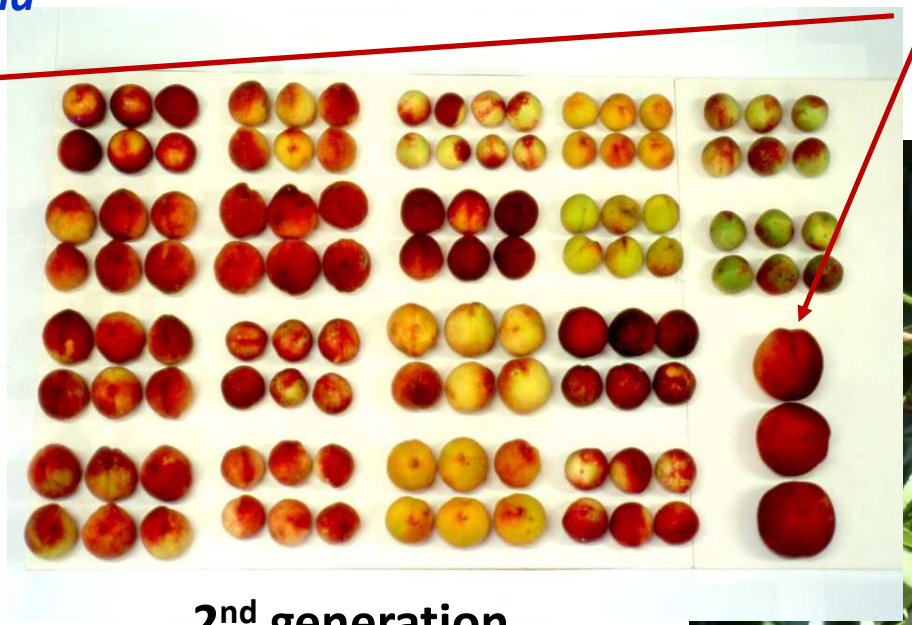
Crosses developed from *Prunus davidiana* and the nectarine Summergrand®

Prunus davidiana

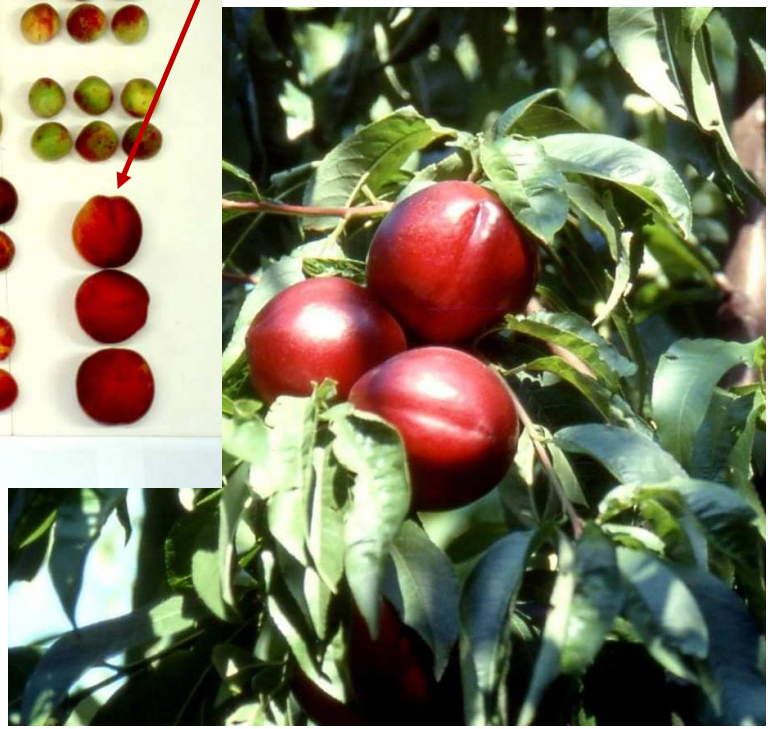
Summergrand



1st generation



2nd generation



3rd generation

- Resistant individuals with satisfactory agronomic level obtained from the 3rd cycle of breeding
- **Could be used as genitors for further crosses**

DNA-informed breeding: summary

Powdery mildew + green peach aphid

- Improved genitors available but commercial agronomic value still to be improved

Leaf curl

- Genitors associating resistance regions evaluated , hybrids underway

Bacterial spot

- A project to select genitors using markers derived from RosBREED (https://www.rosbreed.org/) in association with French breeders underway

Nematodes + green peach aphid

- Individuals associating both resistance regions available (rootstock material)

Quantitative resistances derived from P. davidiana

- Individuals including several regions associated to resistance available for sustainable resistance program

Example of outcome : the work on peach resistance to *Myzus persicae*

Myzus persicae Sulzer
peach-potato aphid or green peach aphid

Agronomy

- a main threat for peach (*Prunus persica*) (primary host)
- and for many other crops as solanaceous vegetables (secondary hosts)
- vector of viruses such as Plum Pox Virus, Sharka (quarantine disease)
- **observed resistance to all pesticides**

Example of outcome : the work on peach resistance to *Myzus persicae*

Rubira®, a peach cultivar resistant to *Myzus*

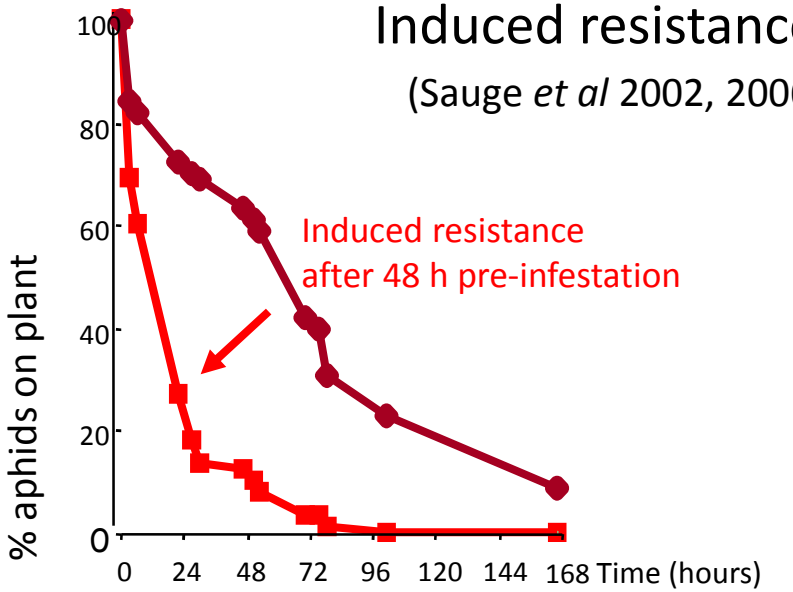
Rubira® a red leaf peach cultivar

- used as rootstock
- Containing a dominant gene of resistance to *Myzus persicae* (***Rm2***)

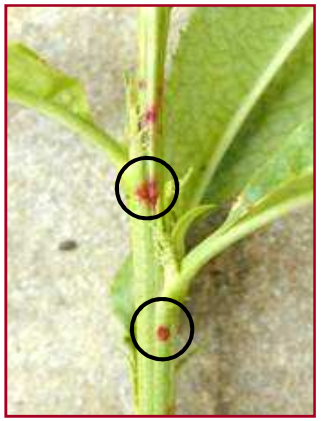
(Pascal *et al*, 2002; Lambert et Pascal, 2011))

Induced resistance occurring two days after infestation

(Sauge *et al* 2002, 2006)



- Running away of aphids from Rubira resistant plants within few days: antixenosis



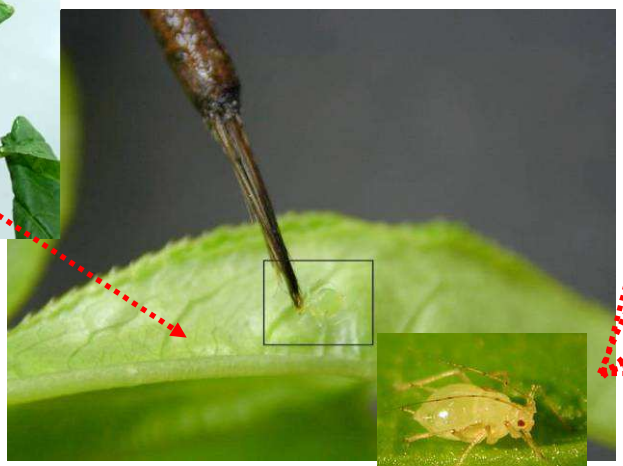
- Local red reaction around feeding sites on Rubira and a green-leaf resistant Rubira hybrid

Example of outcome : the work on peach resistance to *Myzus persicae*

Tests of resistance to Myzus on seedlings of a cross derived from Rubira

In green house on 3month-seedlings

Aphids bred on GF305 peach tree



Controled infestation

Susceptible seedlings

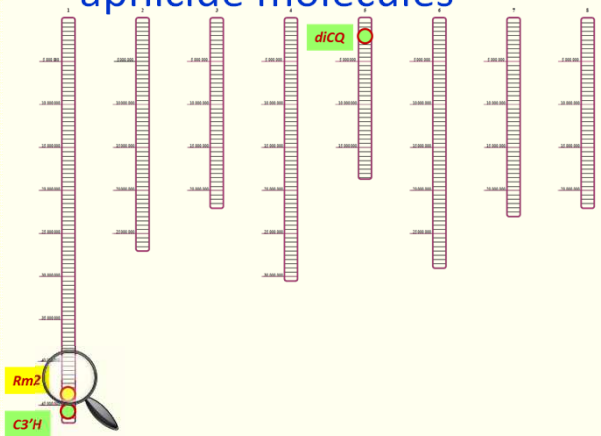
Resistant seedlings

Example of outcome : the work on peach resistance to *Myzus persicae*

Towards natural compounds, safe for human health and the environment, to control aphids

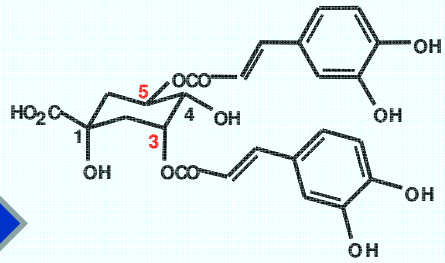
Genetic and functional characterization of peach resistance to *Myzus persicae*

- Identifying and cloning of resistance gene *Rm2*
- Development of markers for DNA-informed selection
- Identifying genes controlling aphicide molecules

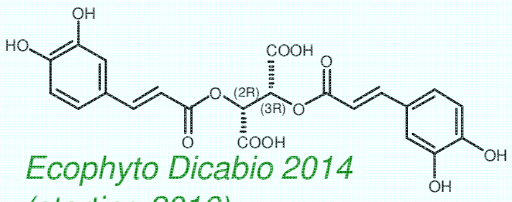


Two phenolic compounds toxic for aphids identified

- Dicaffeoylquinic acid (diCQ)



- Chicoric acid (diCT)



Ecophyto Dicabio 2014 (starting 2016)

• A start-up licensed for our patent on diCQ production from plants

- A new patent granted for aphicide activity of diCT
- **An ongoing contract with a private company to develop theses compounds as biopesticides**

(aphicide and fungicide)

License for the patent 08/00561 april 2013
Patent 14/51341 february 2014

Concluding remarks

- Resistant peach cultivars are one of the most interesting solutions for limiting pests and diseases
  - ➢ in particular when treatments are unavailable

- They could contibute to reducing the use of synthetic pesticides

- They could insure long-term sustainable protection of the orchards when several resistance factors are associated

- The use of DNA-informed methods of selection would allow accelerating development of novel resistant cultivars with good agronomic features

  - ➢ Development of pre-breeding material underway

Personnal involved in peach breeding for resistance– INRA-UGAFL

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Collaborations (sharka)

V. Decroocq, S. Decroocq and D. Tricon

INRA, UMR 619 Biologie du Fruit - Plate-forme Metabolome-Fluxome , BP81, 33883 Villenave d'Ornon

Many thanks for your attention