Worldwide view of breeding for disease resistant grapevine varieties

Not an exhaustive presentation!
Only few examples and challenges to face

Laurent Audeguin
IFV, UMT Geno-Vigne®, F-34060 Montpellier, France
What do we mean by Resistance?

- Biotic stresses (PM, DM, PD, phylloxera, nematodes...)
- Abiotic stresses (cold hardiness, drought, lime...)

A bit of History

For: Wine industry, Table Grape, Juice, Rootstocks...

Current programs: kind of 360° but not an exhaustive one!

« Go » vs « No go »? What’s next?
Worldwide view of breeding for disease resistant grapevine varieties

- **US Hybrids**: > 1800
- **> 1860**: Phylloxera, Powdery Mildew, Downy Mildew... :
  - Rootstocks
  - Hybrids: « HPD »
  - Private breeders +++

- **20th Century**: > 1950
  - Rootstocks +
  - Varieties +++ : production (+++), quality : intra-specific breeding programs mainly (eg: Marselan, Dornfelder...)
  - Public breeders +++
• French vineyards: evolution of « HPD »

From 400 000 ha to +/- 6 000 ha in 50 years!

Source: Jean-Michel Boursiquot
Worldwide view of breeding for disease resistant grapevine varieties

“Legacy” of 1st generation of Hybrids! Specific characteristics and Use

Frontenac: *V. riparia* 89 x Landot 4511
University of Minnesota
Cold hardiness: -30°C
Very disease resistant, with near-immunity to downy mildew

La Crescent: St. Pepin x Swenson selection from *V. riparia* x Muscat de Hambourg
University of Minnesota
Cold hardiness: -30°C
Moderately disease resistant

Vidal 256: Ugni blanc x Rayon d’Or
Canada (Ontario +++)
Cold hardiness
Production of ice wines
Brazil : Table grape and Juice

Niagara :
Concord X Cassady
V labrusca x V vinifera (1868)

BRS Isis :
Red seedless table grape
Tolerant to downy mildew
High yields, berries of natural big size and uniform color, even without chemical treatments.
• “Second generation” of breeding programs ~ 70’s – 80’s

Vitis amurensis – Hybrids x V Vinifera

Germany:


Muscadinia rotundifolia (Run1, Rpv1)

INRA Alain Bouquet, > 1970

From Malaga x M rotundifolia to BC5 (and now BC6) using different V vinifera at each generation. INRA UE Pech Rouge
Worldwide view of breeding for disease resistant grapevine varieties

• Western Europe :
  - Italy 10 000 ha
  - Portugal 8 000 ha
  - Spain 4 000 ha
  - Germany 3 000 ha
  - Switzerland 400 ha

• Eastern Europe :
  - Romania 90 000 ha
  - Ex USSR 80 000 ha
  - Hungary 20 000 ha
  - Ex Yugoslavia 20 000 ha
  - Bulgaria 15 000 ha

• Asia :
  - Japan 15 000 ha
  - Corea 15 000 ha
  - China 10 000 ha
  - India 5 000 ha

• America :
  - USA 50 000 ha
  - Brazil 45 000 ha
  - Canada 5 000 ha
  - Uruguay 4 000 ha

Source : Jean-Michel Boursiquot + OIV, approx 2010
To sum up:

- **Juice production**: Brazil +++
- **Table grape**: Brazil and United States of A.
- **Cold hardiness**: United States of A. (NE) and Canada
- **Other specific productions**: Ice wines (Canada)
- **“Old” vineyards**: (Eastern Europe)
"Third generation" of breeding programs since 2000

- Identification of traits and alleles relevant for breeding
  [http://www.vivc.de](http://www.vivc.de) (PM: 10 +/-, DM: 15 +/-)
- Genome sequence in 2007
- Introgression
- Selection assisted by markers (MAS)
- Pyramiding
Example of INRA Resdur Programs

Worldwide view of breeding for disease resistant grapevine varieties

Source: Didier Merdinoglu
INRA RESDUR 1 : Submission for 2017 registration

INRA BC4 Muscadinia x Regent

Source : Christophe Schneider
INRA RESDUR 1: Submission for 2017 registration

IJ 134

INRA BC 4 Muscadinia X Regent

Source: Christophe Schneider
Worldwide view of breeding for disease resistant grapevine varieties

INRA RESDUR 1 : Submission for 2017 registration

Col-2007G

INRA BC 5 Muscadinia X Villaris

Source : Christophe Schneider
Worldwide view of breeding for disease resistant grapevine varieties

INRA RESDUR 1: Submission for 2017 registration

INRA BC 5 Muscadinina X Villaris

Source: Christophe Schneider
Breeding programs in Australia

Worldwide view of breeding for disease resistant grapevine varieties

Mark Thomas, Ian Dry, Peter Clingeleffer

- CSIRO AGRICULTURE AND FOOD
CSIRO: main (only) research institution in Australia breeding new grapevine varieties

- Scions and rootstocks for 3 industries
  - wine
  - table grape
  - dried fruit

Industry focus:
- Reduced inputs & costs
- Quality product
- Resilience to climate change
- Environmental sustainability

Research supported by industry:
Wine Australia
Horticulture Innovation Australia (HIA) – table and dried fruit industries
Scions (wine, table, dried fruits),
Traits of Interest

- Powdery Mildew and Downey Mildew resistance
- Yield
- Fruit composition and wine quality
- Better suited to Australian conditions (climate change)
Origin of new traits

Biotic resistance and abiotic tolerance:

- American species
  - *Muscadinia rotundifolia* (mildew resistance, e.g. RUN1)
  - *Vitis amurensis* (mildew resistance)
  - *Vitis cinerea* (root pest resistance)
  - *Vitis berlandieri*
  - Complex hybrids

- Asian species
  - *Vitis romanetti* (mildew resistance)
  - *Vitis piasezkii* (mildew resistance)

Long-term focus is durable resistance – trait stacking from different species
Strategy for scions and rootstocks

Changed from traditional breeding to marker-assisted selection (MAS) to improve the process

Stage 1: Breeding of new selections

Stage 2: Field performance, fruit and wine evaluation of new selections and existing varieties ( >5,000 since 2010 )

Stage 3: Identification of superior selections for further evaluation and regional trials ( >800 )

Stage 4: Small scale testing with interested companies

Stage 5: Commercial release
Wine industry challenges for new scion adoption

How to market new varieties?
- variety label or non-varietal label (winery, region)
- no marketing, just use in blending

Timeframe for adoption?
- May depend on enterprise size and risk versus benefits
  - slow with increasing scale to reduce risk (20-30 years)?
  - fast with higher risk (10-20 years)?
Breeding programs in USA

- Resistance to PM&DM, Cornell University

- Released 2013
- First identified 2001
- Tested in “no-spray” vineyards
- Highly disease resistant – PM, DM, Botrytis
- Harbors Ren2
- Cold hardiness : 25 C
- Upright growth habit
- Wines : densely colored, light to moderate tannins

Source : Bruce Reisch
Breeding programs in USA

- Resistance to PM&DM, Cornell University

Disease resistant red wine grape

Highly resistant to downy mildew, powdery mildew and black rot

It harbors loci Rpv1, Run1, and Ren2.

Source: Bruce Reisch
Breeding programs in USA

- Resistance to **PM&DM**, Cornell University

NY12.0107. (2012)

Selected with markers for **Run1, Rpv1 and Ren2**

Cluster and vine characteristics suitable

**Flavor free of wild species characteristics**

To be propagated for wine trials in the next future

NY12.0107

Source: Bruce Reisch
Breeding programs in USA

• Resistance to Pierce Disease, UC Davis

Source: PDR1 (Vitis arizonica)

50% Petite Sirah, 25% Cab-Sauvignon

Early bloom, early ripening

Relatively large berries, medium large clusters

Medium productivity

Source: Andy Walker
Worldwide view of breeding for disease resistant grapevine varieties

Breeding programs in USA

• Resistance to Pierce Disease, UC Davis

Source: PDR1 (Vitis arizonica)

50% Zinfandel, 25% Durif, 12.5% Cab-Sauvignon

Late bloom, mid-season ripening

Relatively large berries, large clusters

Moderate-low productivity

Source: Andy Walker
Breeding programs in USA

- Resistance to DM, Botrytis, MSU, Chin-Feng Hwang

Downy mildew, Botrytis Bunch Rot, Rooting ability

Sources of resistances: *Vitis aestivalis*-derived ‘Norton’

Agenda: ?

Number of genotypes under evaluation:
~250 F1 of Norton x Cabernet-Sauvignon

Release Norton-based cultivars for wine industry

Source: Chin-Feng Hwang
Breeding programs in USA

• Private sector

Continuous improvement of fruit and wine quality, including wine grape sector (Gallo) and table grape sector (IFG).

Schedule for the introduction or adoption of improved plant material: challenging to delineate. Because of continuous improvement!

Shared aspects for disease resistance breeding and clonal improvement: selection and evaluation for freedom from bunch diseases, such as botrytis bunch rot and sour rot.

“Compact clusters = bunch diseases. Strong interest of new plant materials with loose clusters”. P Cousins. Gallo
Mostly focused on Downy and Powdery mildew. Low resistance in good quality table grapes then using wine grapes to introduce resistance in table grape program. Resistance donors: mainly “older” French-hybrids like Villard Blanc and Villard Noir, Chambourcin, etc) and newer cultivars like Regent and then also Kishmish Vatkana, …

Use of SSR markers

In process of pyramiding genes: off-spring in greenhouses being screened for Rpv3, Ren3 and Ren1. (Villard Blanc x Red Globe) times Kishmish Vatkana

Very recently: crosses for wine grapes, but no vines are in the fields yet.

Source: Phyllis Burger
What’s going on in New Zealand?

Recent slight move toward research in Grapevine genetics mostly driven by Plant and Food research
Work driven by researchers rather than NZW.
Current work based around creating a “Mutant population” by exposing cell tissue to chemical stress and causing some mutations

Plan to grow 40,000 of these “mutant” plants most likely half Sauvignon Blanc and half Pinot Noir and screen these vines for desirable traits like disease tolerance
The researchers view this as fast forwarding clonal selection.

“Pretty random and untargeted way”?

Source: Nick Hoskins, Riversun Nursery
No breeding program known for fungi resistance?

INIA La Platina in Santiago:

Working on Genome editing...
Just setting up the technique aiming to work with table grapes mostly
Primary focus of the group: Botrytis

Source: Yerko Moreno, Universidad de Talca, CTV.
Worldwide view of breeding for disease resistant grapevine varieties

And Europe?

- **Main actors**: public institutes, semi-public institutes, private breeders
  - **Germany**: Geisenheim, Julius Kühn Institut, WBI
  - **Switzerland**: Agroscope Changins, V Blattner
  - **Italy**: Istituto de Genomica Applicata, CRA-VIT Conegliano
  - **France**: INRA, IFV
  - **Hungary**: Szőleszeti es Boraszati Kutatointezet (SZBKl) Pécs

**General strategy**: Pyramiding (sources: Vitis US, Muscadinia, Vitis amurensis, Kishmish vatkana)

Source: Les Cépages résistants, ICV
 Worldwide view of breeding for disease resistant grapevine varieties

New French programs

Wild species
✓ **Resistant to** fungi diseases (2 QTLs PMDM)
✗ **Defaults**: growing aptitudes and wines -

V. *vinifera*
✓ **Quality and « Typicity »**
✗ **Susceptible to** fungi diseases

New genotypes
✓ Resistant **to** PM and DM
✓ Sustainable **resistance**
✓ Adapted to **winegrowing regions**
✓ Adapted to **Climate Change**

Source: Christophe Schneider
Worldwide view of breeding for disease resistant grapevine varieties

- **Champagne + Burgundy - CIVC-BIVB**
  Pinot, Chardonnay, Gouais X GENOTYPE RESISTANT (2 or + QTLs PM DM)

- **Cognac - BNIC**
  Ugni blanc, Folle Blanche, Colombard, Folignan X GR

- **Bordeaux - CIVB**
  Cabernet franc, Petit Verdot, Carmenère X GR

- **Rhone Valley – Inter-Rhône**
  Grenache, Syrah X GR

- **Rosés - CIVL CIVP Centre des rosés (EDGARR, Genomic selection)**
  Vermentino, Cinsaut X GR

- **And also in 2016 : Alsace, Martell**

- **Raisin de Table**
  Muscat d’Alexandrie, Centennial Seedless, Alphonse Lavallée X GR

Starting in 2013/2014...........Official Releases = expected > 2028
To conclude:

- Faster changes and development for Table grape and Juice / Wine industry
- Variable interest and involvement / countries (environmental conditions, market,....)
- but +/- all wine countries involved now!
- Recent growing demand in France
- Health issues and economical issues
- Public powers to encourage the movement
What’s next?

- Sources of resistance: non renewable resources?
- Nature vs Emptiness: other fungi diseases?

Recommendation for a minimum spraying / regions

Observatory of sustainability (INRA UMR SAVE + IFV)

Limited and controlled development of « Run Material » (Bouquet cultivars) for Juice and ...other use?
Considering:

- PM and DM: +++ diseases at a world scale
- Efforts of introgression
- Risks of break down
- Recent improvement (ie: MAS)

Recommends:

- Obtaining new material carrying more than one QTL
- Appropriated spraying programs to protect sources of resistance
Extrait du règlement européen 1308-2013, article 93 :

1. Aux fins de la présente section, on entend par :

a) "appellation d'origine", .........................

i) sa qualité et ses caractéristiques sont dues essentiellement ou exclusivement à .................

ii) il est élaboré exclusivement à partir de raisins provenant de .................

iii) sa production est limitée à la zone géographique considérée .................

iv) il est obtenu exclusivement à partir de variétés de vigne de l'espèce Vitis vinifera
• What’s next?

➢ New “conditions” in France

Since May 2016, « opening » of Official Catalogue to new material for temporary registration

DUS done : 20 ha x 10 max in France

DUS not yet completed : 3 ha max in France

Demands being currently evaluated by Ministry of Agriculture for 25+ varieties, eg : Souvignon gris, Prior, Monarch (D), Divico, Pinotin (CH), Soreli, Fleurtai (I)....
Worldwide view of breeding for disease resistant grapevine varieties

• What’s next?

➢ First round of new material: transitional, 85/15?
➢ Climate change?
➢ Adoption by consumers?
➢ On the long run? (eg: French program with winegrowers associations)
➢ New technologies:
  ➢ Routine use of screening with markers (MAS)
  ➢ High throughput tools (genotyping + phenotyping), GBS
  ➢ Genome Editing: Feasibility, GMOs or « hidden » GMOs or not?
Worldwide view of breeding for disease resistant grapevine varieties
Special thanks to:

Bruce Reisch, Peter Cousins, Andy Walker, Nick Dokoozlian, Chin-Feng Hwang, Mark Thomas, Phyllis Burger, Reinhard Töpfer, Anne-Françoise Adam Blondon, Laurent Torregrosa, Didier Merdinoglu, Christophe Schneider, Laurent Delièvre, Loïc Le Cunff, Jean-Michel Boursiquot, Edgar Sinigaglia, Yerko Moreno, Nick Hoskins, and Groupe ICV

And apologies for those I did not mention!