A key to sustainable management of grapevine resistance : a case study with downy mildew

François Delmotte, Chloé Delmas, Yann Dussert, Isabelle Demeaux, Sylvie Richart-Cervera, Carole Couture, Frédéric Fabre, Laurent Delière

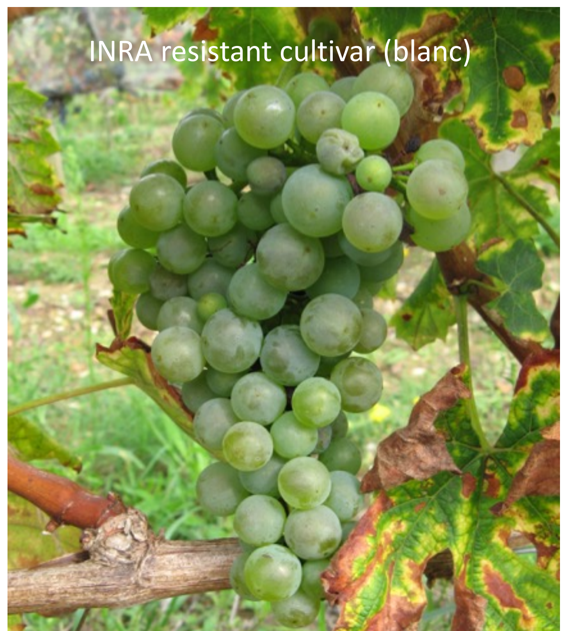
INRA Bordeaux, France

- Decreasing significantly (>50%) the grapevine dependency upon fungicides necessarily involves a "breakthrough".

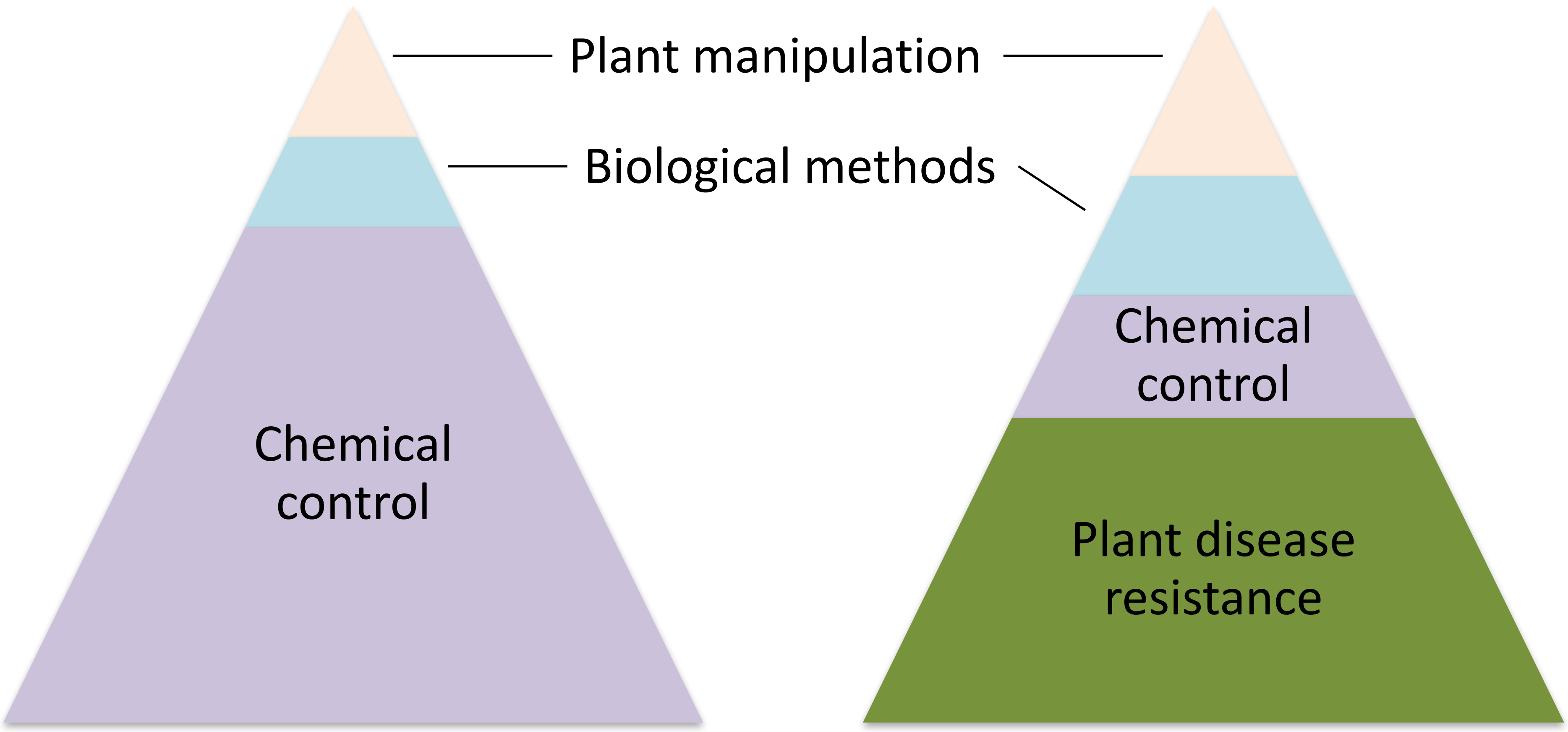
- In this line, the use of natural grapevine resistance against pathogens is certainly the most promising "innovation" to reduce fungicide treatments.

Resistances are present in north america where Vitis species have coevolved with the pathogens

- New grapevine varieties showing low to high level of resistance to powdery and downy mildew are now registrated in Europe.
- Contrary to « old interspecific hybrids », these newly bred varieties present good cultural and oenological features.

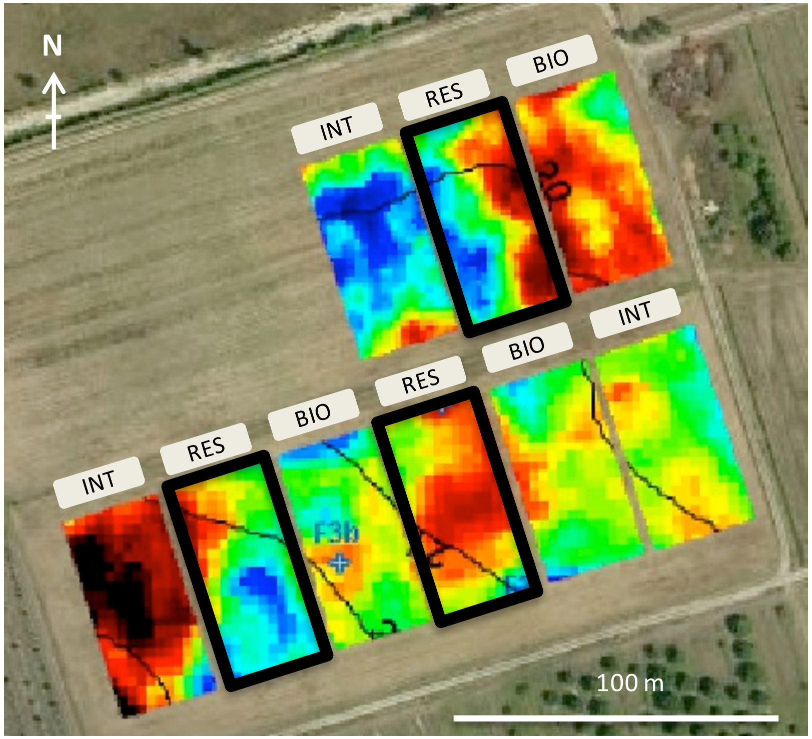


Moving on towards a more balanced cropping system



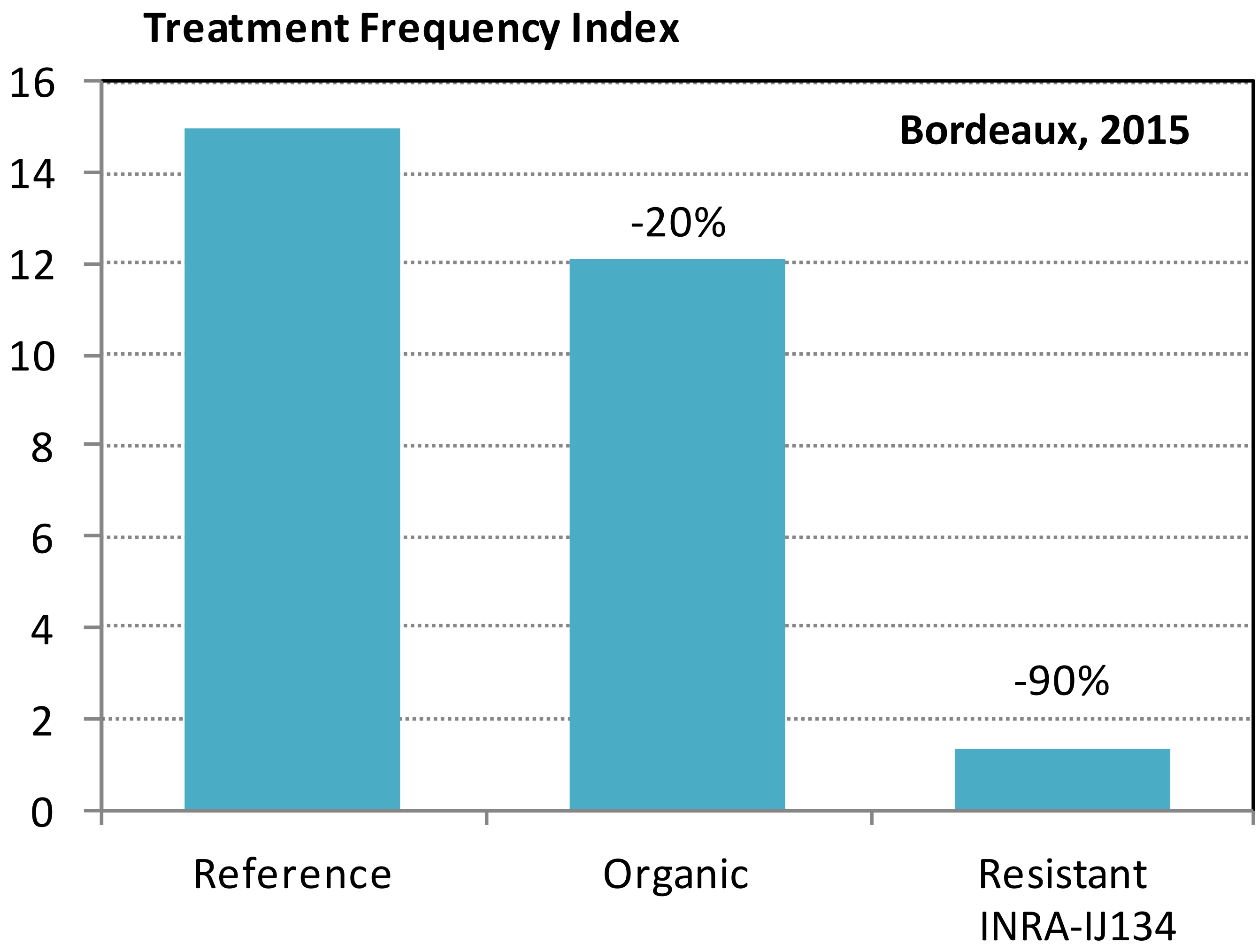
LONG-TERM AGRONOMICAL AND ECONOMICAL PERFORMANCES OF LOW INPUT WINE-GROWING SYSTEMS

System	cultivar	strategy
RES	**Resistant variety**	**Low-input**
INT	Merlot	IPM
BIO	Merlot	ORGANIC



Plantation	*2011*
Density	*6580 ceps/ha*
Total area	*1,8 ha*
Design	*3 replicates of 0,2 ha*
Assessment	• *Yield* • *Disease prevalence* • *Labour time* • *Costs* • *Wine quality* • *Pesticide residus*

TOWARDS LOW INPUT WINE-GROWING SYSTEMS



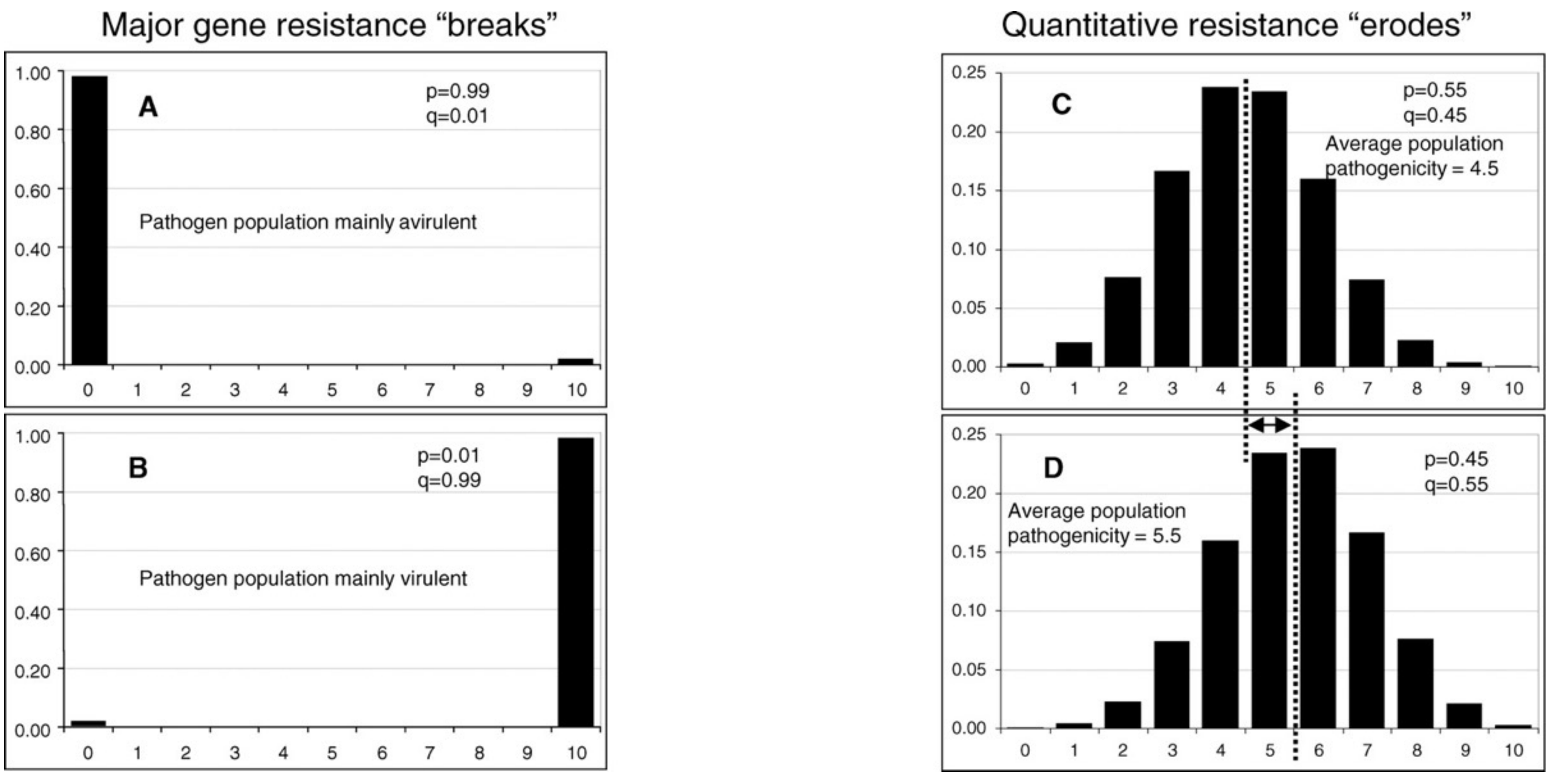
The other side of the coin : R-genes durability

- However, we need to make sure that the resistance employed not only is effective, but also persists in time, despite the constant evolution of pathogens.

- The durability of resistance is especially important in perennial species like grapevine which are meant to stay in the field for at least 20 years.

- We know from results obtained in many other pathosystems that plant R-genes are not « everlastings »…

Plant resistance genes are not « everlastings »



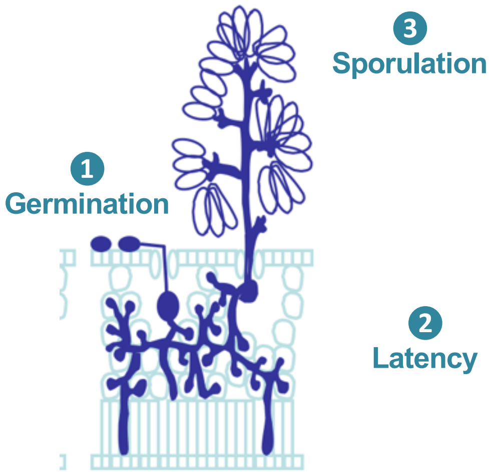
What makes a resistance durable ?

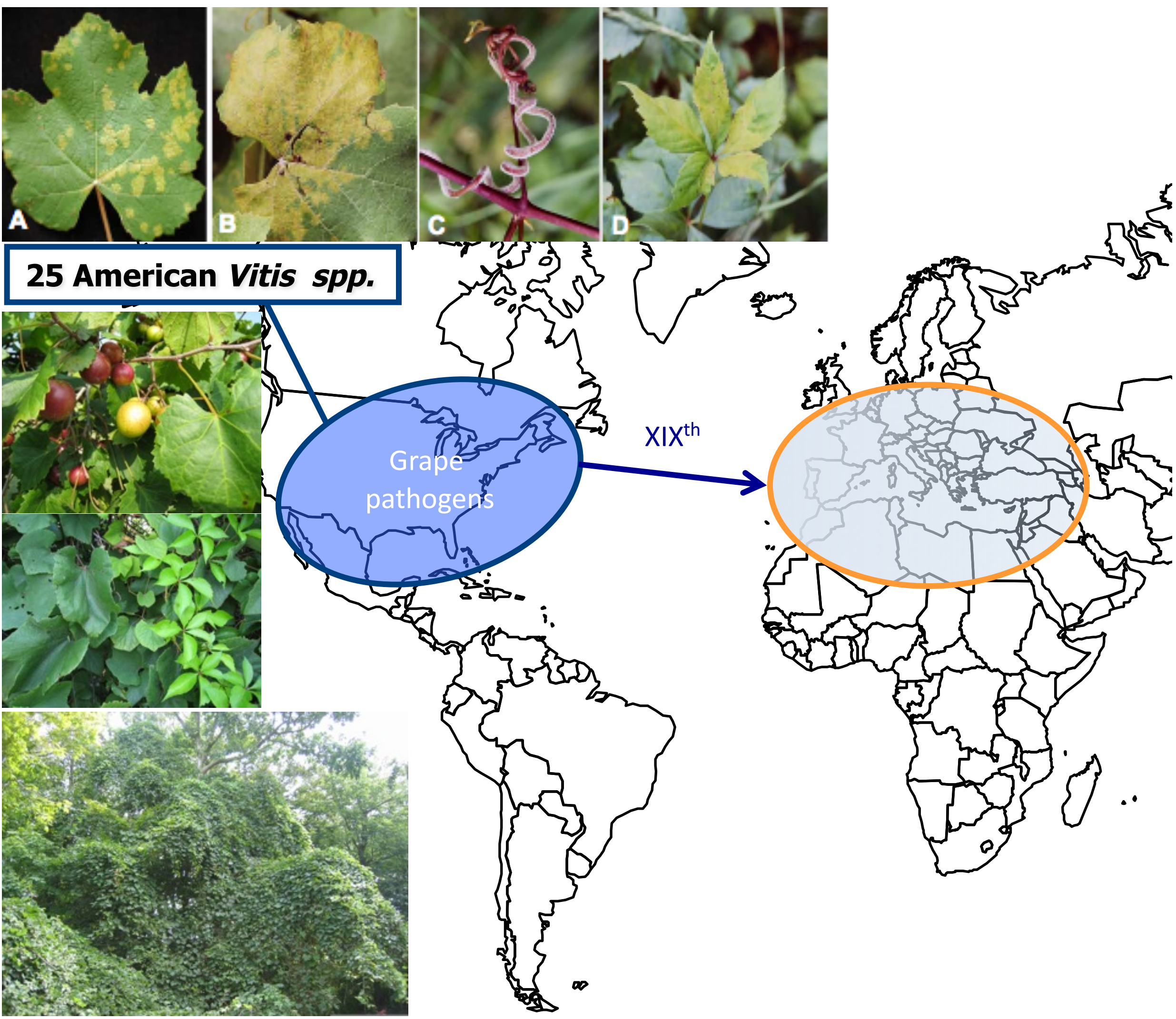
- The nature of resistance genes and the interaction with pathogen effectors is important (total vs partial resistance)

- The evolutionnary constrains related the the modification of the corresponding avr gene in the pathogen => the so-called 'Cost of virulence'

- The evolutionnary potential of pathogen populations

    ✓ Genetic diversity, reproductive system, population effective sizes, gene flow, etc.





Grapevine downy mildew is an oomycete, Stramenopiles

Plasmopara viticola is a native species from North America

P. viticola attacks a large range of *Vitis* spp. in north America

New Phytologist

Research

Phylogenetic and experimental evidence for host-specialized cryptic species in a biotrophic oomycete

Mélanie Rouxel[1,2], Pere Mestre[3,4], Gwenaelle Comont[1,2], Brian L. Lehman[5], Annemiek Schilder[5]* and François Delmotte[1,2]*

[1]INRA, ISVV, UMR1065 Santé et Agroécologie du Vignoble, F-33883, Villenave d'Ornon, France; [2]Université de Bordeaux, ISVV, UMR1065 Santé et Agroécologie du Vignoble, F-33883, Villenave d'Ornon, France; [3]INRA, UMR1131 Santé de la Vigne et Qualité du vin, F-68000, Colmar, France; [4]Université de Strasbourg, UMR1131 Santé de la Vigne et Qualité du vin, F-68000, Colmar, France; [5]Department of Plant Pathology, Michigan State University, East Lansing, MI, 48824, USA

Ecology and Epidemiology

e-Xtra*

Rouxel et al. , Phytopathology 2014

Geographic Distribution of Cryptic Species of *Plasmopara viticola* Causing Downy Mildew on Wild and Cultivated Grape in Eastern North America

Mélanie Rouxel, Pere Mestre, Anton Baudoin, Odile Carisse, Laurent Delière, Michael A. Ellis, David Gadoury, Jiang Lu, Mizuho Nita, Sylvie Richard-Cervera, Annemiek Schilder, Alice Wise, and François Delmotte

First, fifth, tenth, and thirteenth authors: INRA, ISVV, UMR1065 Santé et Agroécologie du Vignoble, F-33883, Villenave d'Ornon, France; second author: INRA, UMR1131 Santé de la Vigne et Qualité du Vin, F-68000, Colmar, France; third author: Virginia Tech, Department of Plant Pathology, Physiology, and Weed Science, 417 Price Hall, Blacksburg 24061; fourth author: Agriculture and Agri-Food Canada, 430 Gouin Boulevard, Saint-Jean-sur-Richelieu, Quebec J3B 3E6, Canada; sixth author: Ohio State University, Department of Plant Pathology, 224 Selby Hall, Wooster; seventh author: Cornell University, Plant Pathology and Plant-Microbe Biology, 115 Barton Laboratory, NYSAES, Geneva, NY; eighth author: Florida Agricultural and Mechanical University, Center for Viticultural Sciences and Small Fruit, Tallahassee 32307; ninth author: Virginia Tech, Department of Plant Pathology, Physiology, and Weed Science, 595 Laurel Grove Road, Winchester 22602; eleventh author: Department of Plant Pathology, Michigan State University, East Lansing 48824; and twelfth author: Cornell University, Long Island Horticultural Research & Extension Center, 3059 Sound Avenue, Riverhead, NY 11901.

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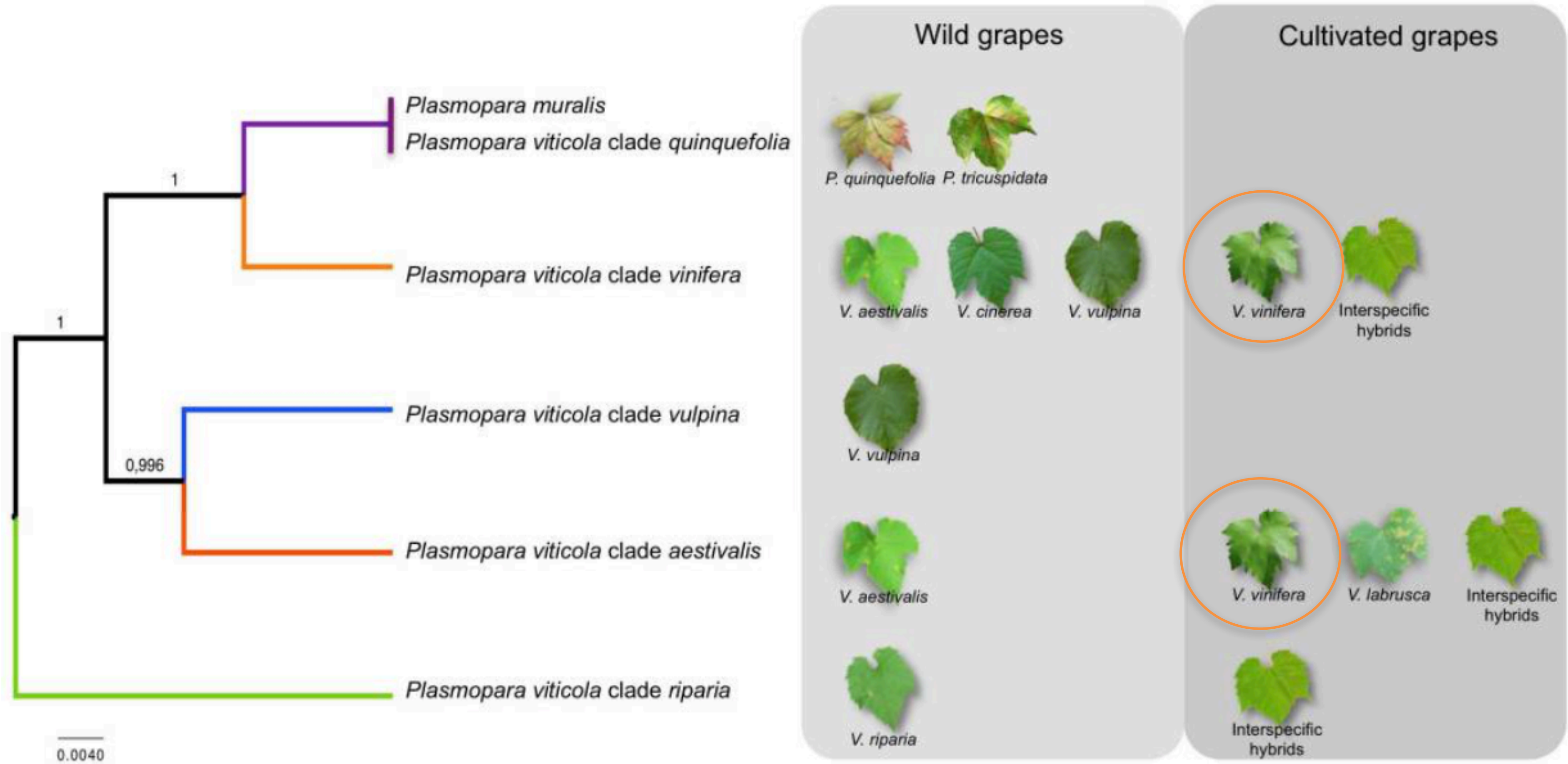
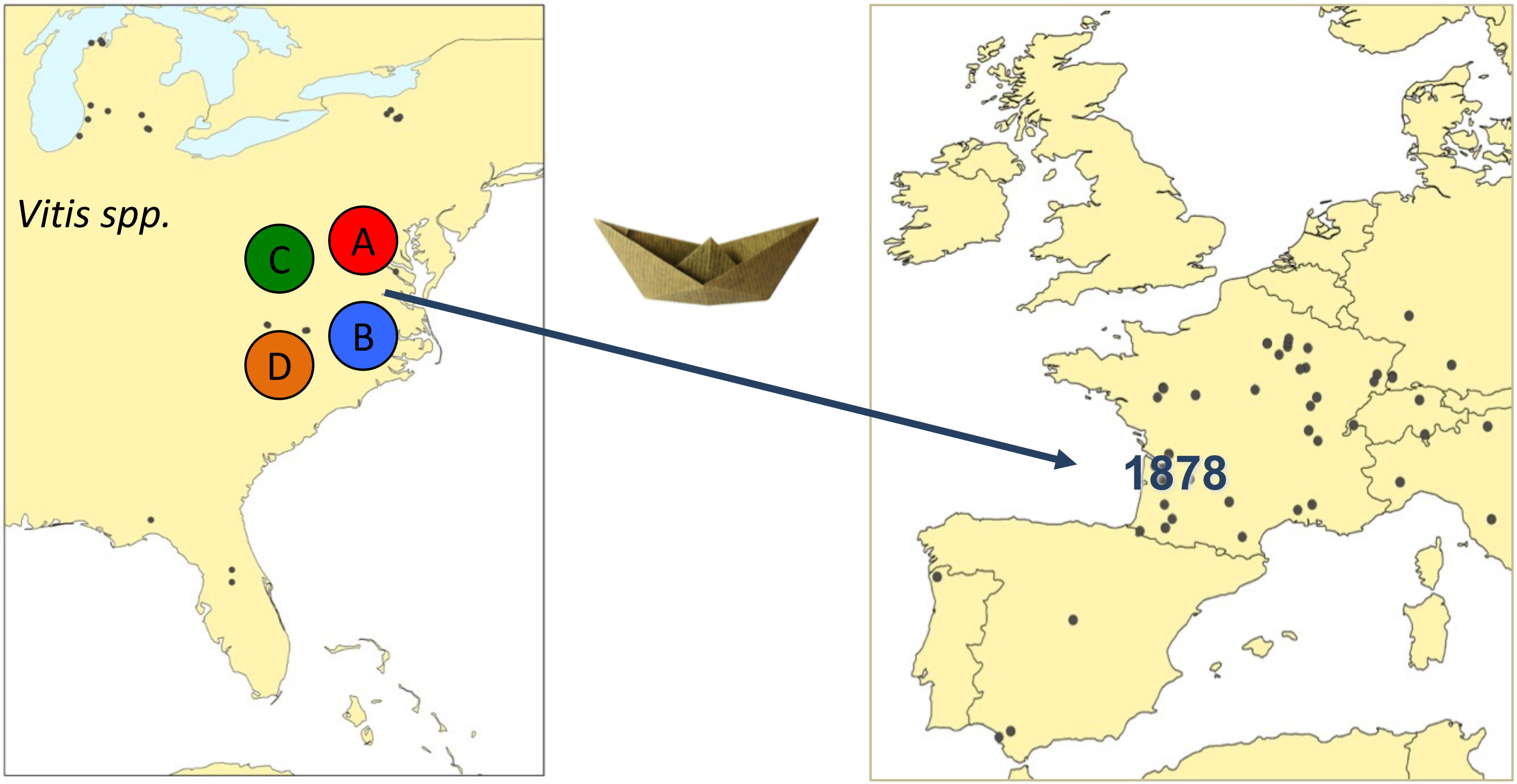
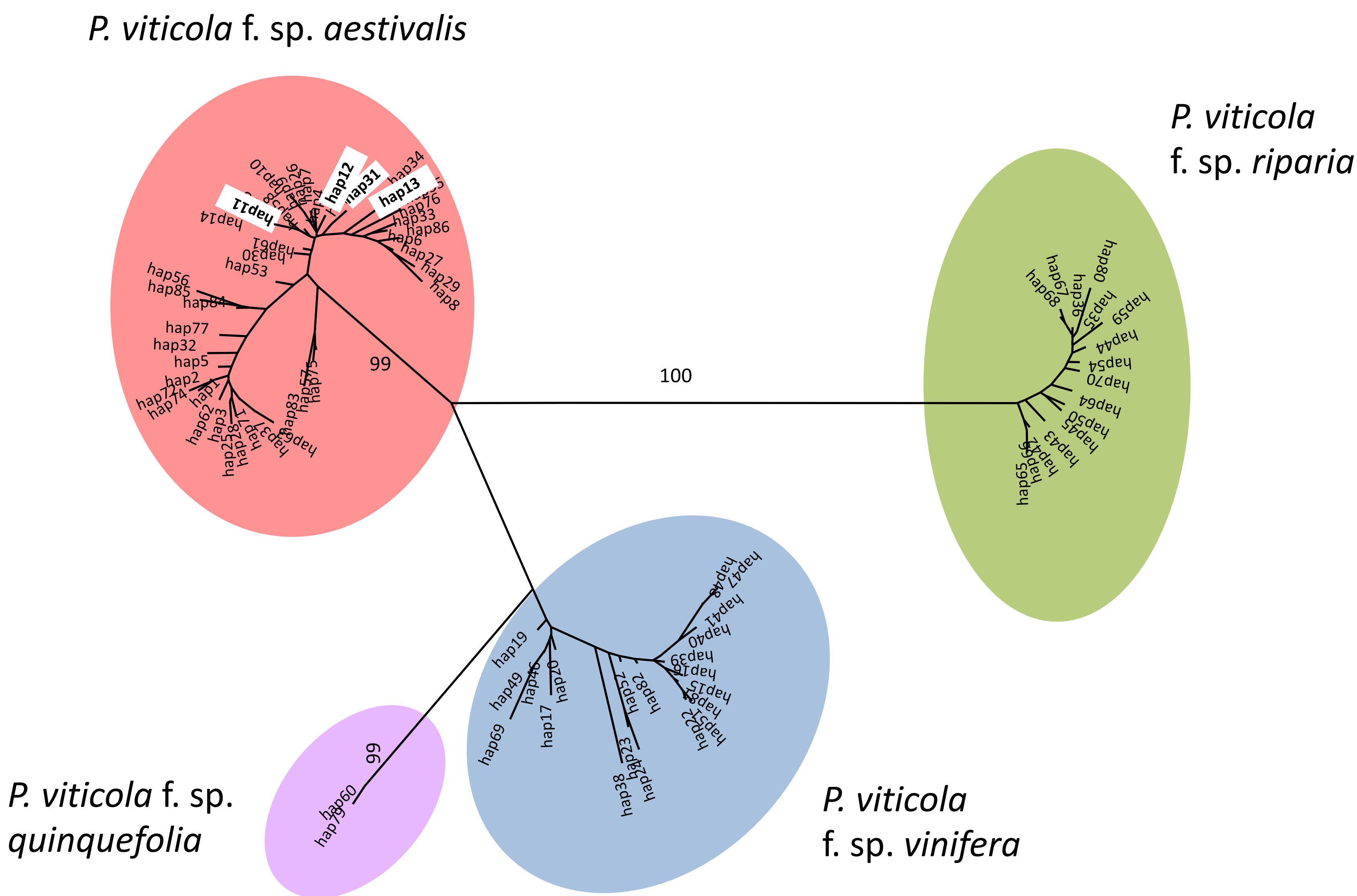
ABSTRACT

In its native range, P. viticola is a complex of several crytic species that are host specialized on wild and cultivated vitis spp.





Vitis spp.
A
C
B
D
1878



β-tubulin gene

83 haplotypes

MOLECULAR ECOLOGY

Molecular Ecology (2013) doi: 10.1111/mec.12293

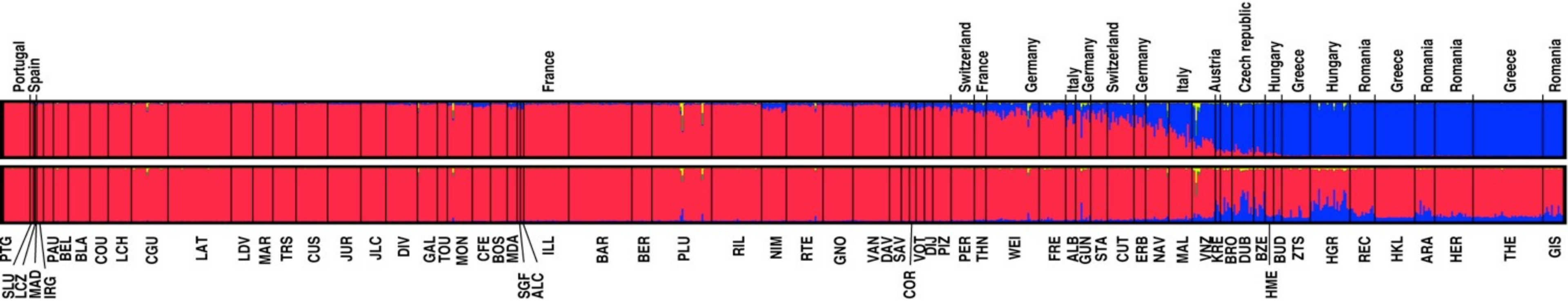
Genetic signature of a range expansion and leap-frog event after the recent invasion of Europe by the grapevine downy mildew pathogen *Plasmopara viticola*

MICHAEL C. FONTAINE,*† FRÉDERIC AUSTERLITZ,*† TATIANA GIRAUD,* FRÉDÉRIC LABBÉ,* DACIANA PAPURA,‡ SYLVIE RICHARD-CERVERA‡ and FRANÇOIS DELMOTTE‡

*Ecologie, Systématique et Evolution, UMR 8079 Université Paris Sud Laboratoire Ecologie, Systematique et Evolution, UMR8079, Orsay Cedex, F-91405, France, †Eco-Anthropologie et Ethnobiologie, UMR 7206 CNRS, MNHN, Univ Paris Diderot, Sorbonne Paris Cité, F-75231 Paris Cedex 5, France, ‡INRA, UMR1065 Santé et Agroécologie du Vignoble, ISVV, F-33883 Villenave d'Ornon Cedex, France

Abstract

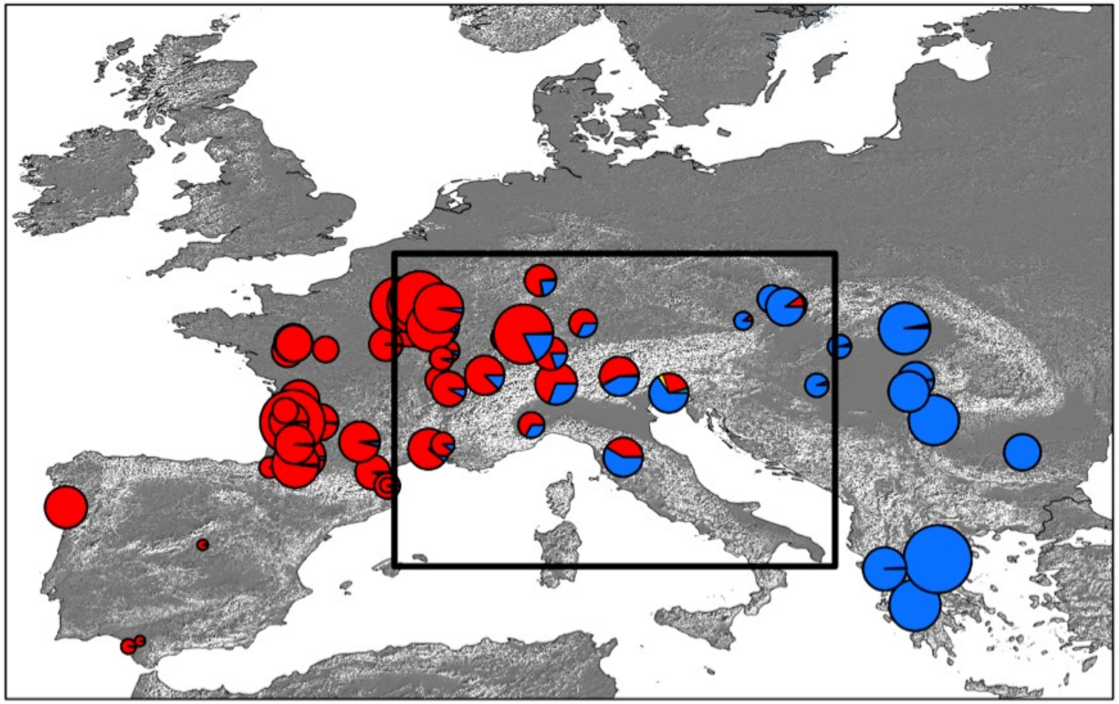
Biologic invasions can have important ecological, economic and social consequences, particularly when they involve the introduction and spread of plant invasive pathogens, as they can threaten natural ecosystems and jeopardize the production of human food. Examples include the grapevine downy mildew, caused by the oomycete *Plasmopara viticola*, an invasive species native to North America, introduced into Europe in the 1870s. We investigated the introduction and spread of this invasive pathogen, by



- ***Very low genetic differentiation***

- $\boldsymbol{F_{ST}}$ **= 0,020 ***

- **low but significant IBD at the continental scale**



- A risk related to re-introductions of the pathogen into Europe
- Efficient sexual reproduction
- Large population effective size and important gene flow at large geographical scales

→ High evolutionary potential

P. viticola is evolving evolve in response to plant resistance deployment

Peressotti *et al. BMC Plant Biology* 2010, **10**:147
http://www.biomedcentral.com/1471-2229/10/147

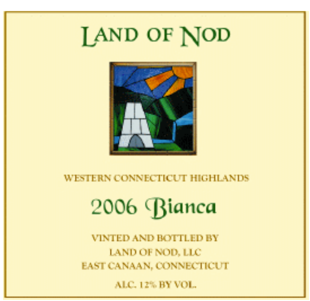
BMC Plant Biology

RESEARCH ARTICLE Open Access

Breakdown of resistance to grapevine downy mildew upon limited deployment of a resistant variety

Elisa Peressotti[1,4], Sabine Wiedemann-Merdinoglu[1,2], François Delmotte[3], Diana Bellin[4,6], Gabriele Di Gaspero[4,5], Raffaele Testolin[4,5], Didier Merdinoglu[1,2], Pere Mestre[1,2*]

Bianca



- Villard Blanc x Bouvier : Bianca
- Cultivated in Hongaria (<1000 ha)
- One strain of P. viticola breaks down the Rpv3 resistance…

Infection, Genetics and Evolution 27 (2014) 500–508

Contents lists available at ScienceDirect

Infection, Genetics and Evolution

journal homepage: www.elsevier.com/locate/meegid

Rapid and multiregional adaptation to host partial resistance in a plant pathogenic oomycete: Evidence from European populations of *Plasmopara viticola*, the causal agent of grapevine downy mildew

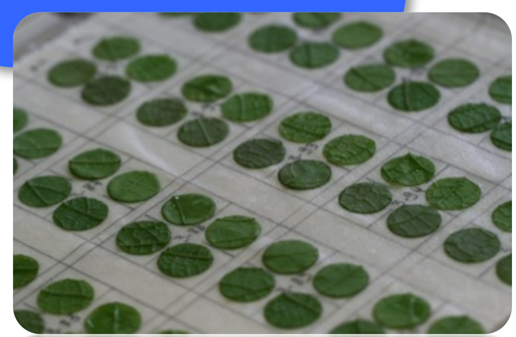
François Delmotte [a,b,*], Pere Mestre [c,d], Christophe Schneider [c,d], Hanns-Heinz Kassemeyer [e], Pál Kozma [f], Sylvie Richart-Cervera [a,b], Mélanie Rouxel [a,b], Laurent Delière [a,b]

[a] INRA, Institut des Sciences de la Vigne et du Vin, UMR1065 Santé et Agroécologie du Vignoble, F-33883 Villenave d'Ornon, France
[b] Université de Bordeaux, ISVV, UMR1065 SAVE, F-33883 Villenave d'Ornon, France
[c] INRA, UMR 1131 Santé de la Vigne et Qualité du Vin, F-68000 Colmar, France
[d] Université de Strasbourg, UMR 1131 Santé de la Vigne et Qualité du Vin, F-68000 Colmar, France
[e] Staatliches Weinbauinstitut, Merzhauser Strasse 119, 79100 Freiburg, Germany
[f] University of Pécs, Research Institute for Viticulture and Oenology, H-7634 Pécs, Pázmány Péter u.4, Hungary

Testing for pathogen adaptation to partial resistance

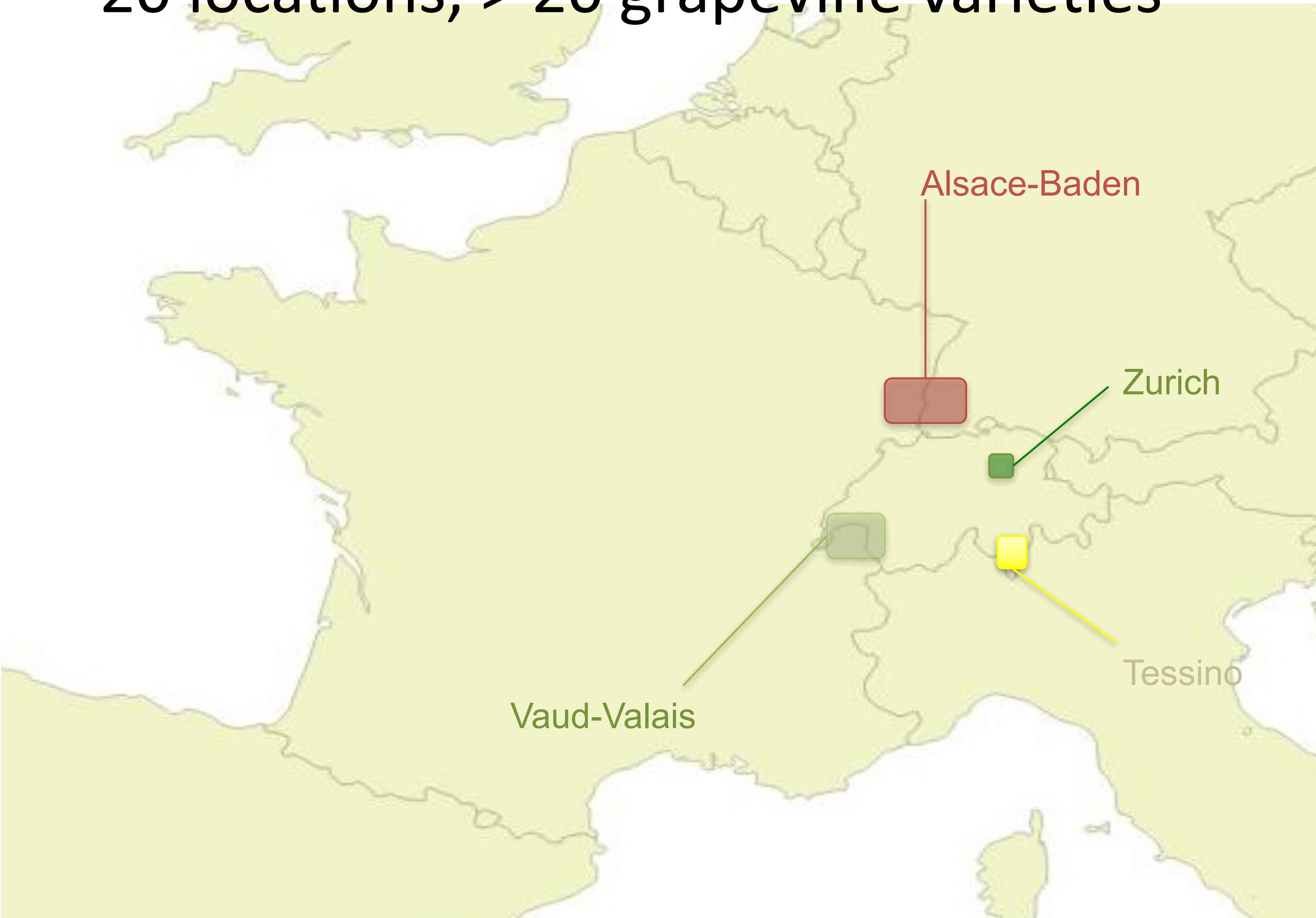
Large scale sampling of *P. viticola* isolates

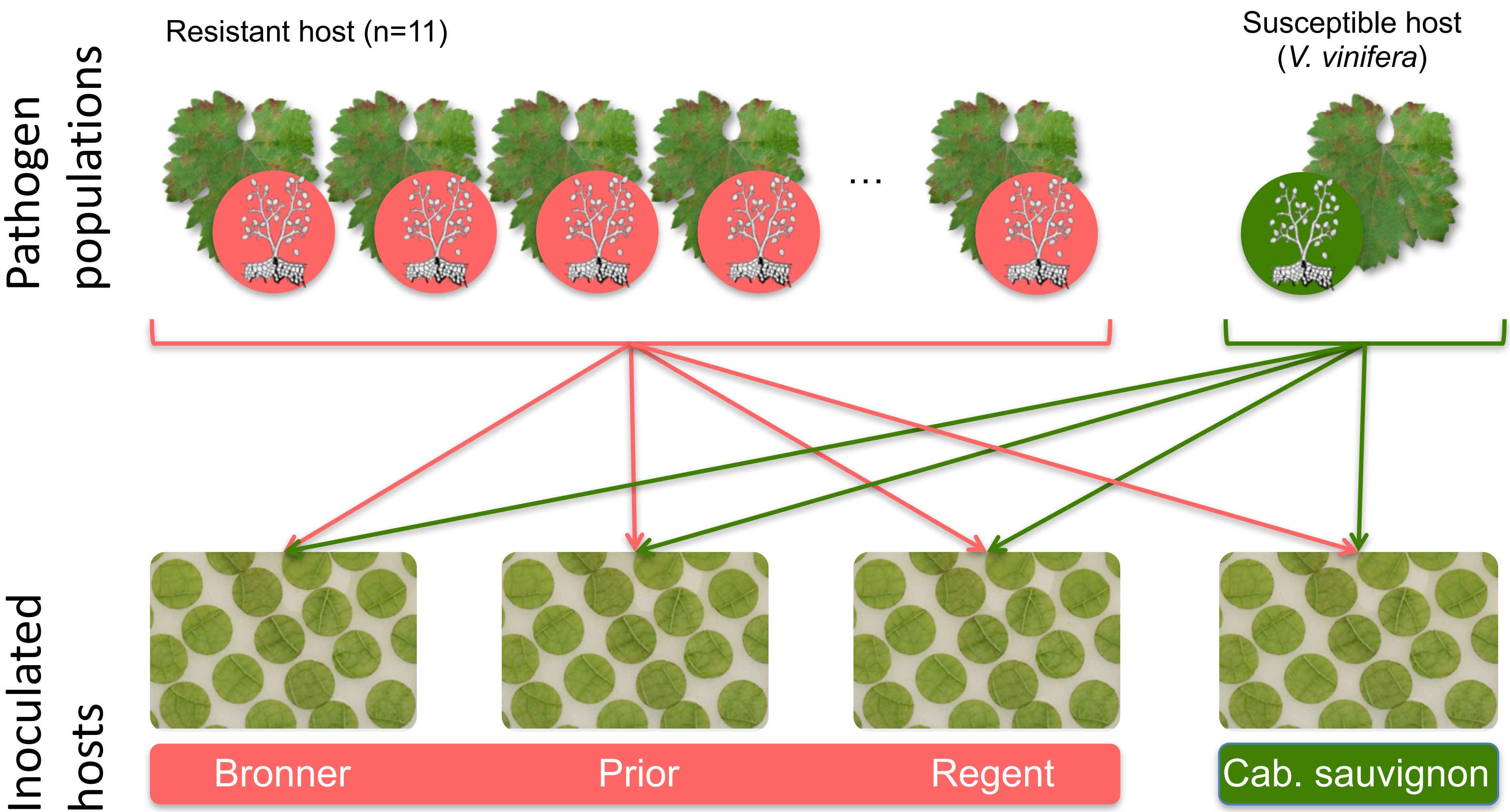
Inoculation of host plants with pathogen isolates



Pathogen life-cycle quantitative traits assessment

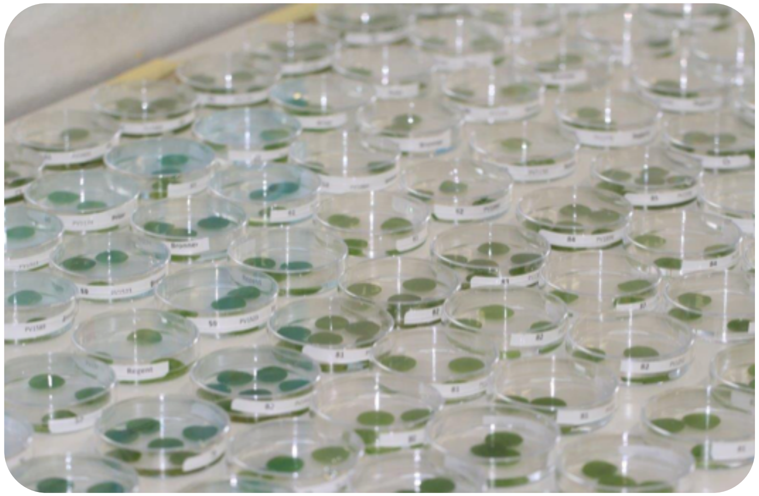
Sampling design --- [n=103]
20 locations, > 20 grapevine varieties




Pathogen populations
Resistant host (n=11)
Susceptible host (V. vinifera)
...
Inoculated hosts
Bronner
Prior
Regent
Cab. sauvignon

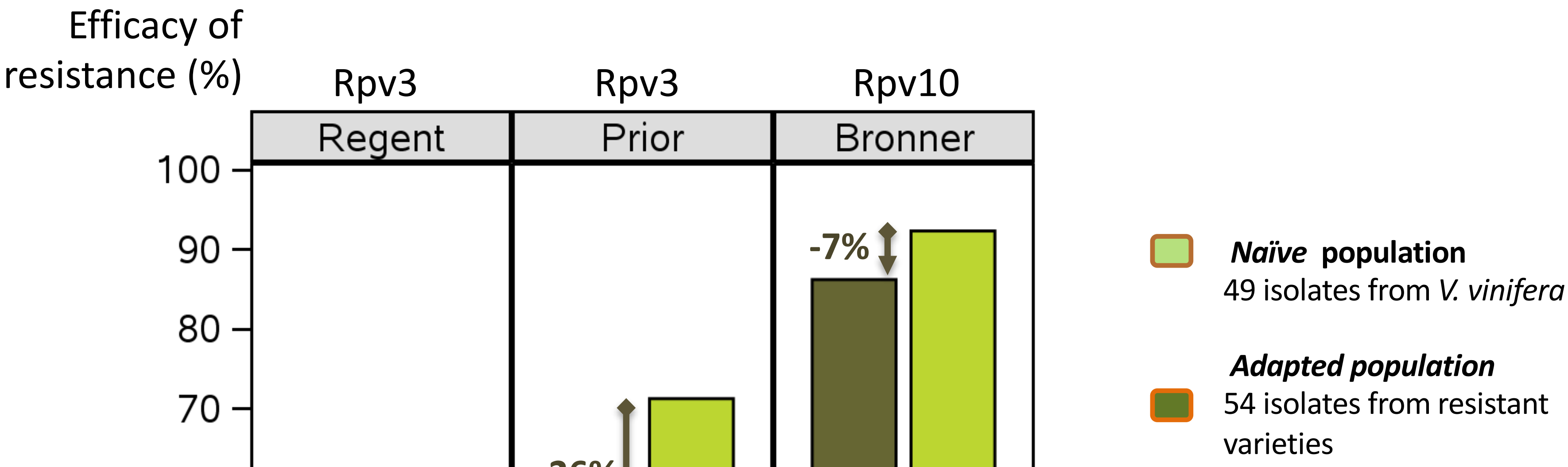
A unique bioassay

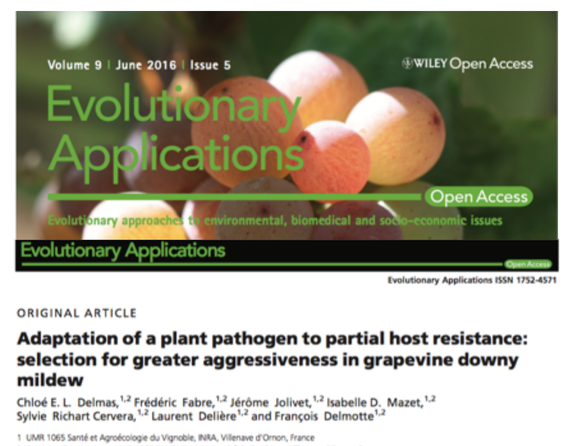
- 103 isolates * 4 plants
- 412 interactions
- 1545 leaf discs



- Sporangial production
- Sporangia size
- Latent period
- Sporulation dynamics
- Number of zoospore

An undergoing erosion of grapevine partial resistance





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Evolutionary Applications

Evolutionary Applications ISSN 1752-4571

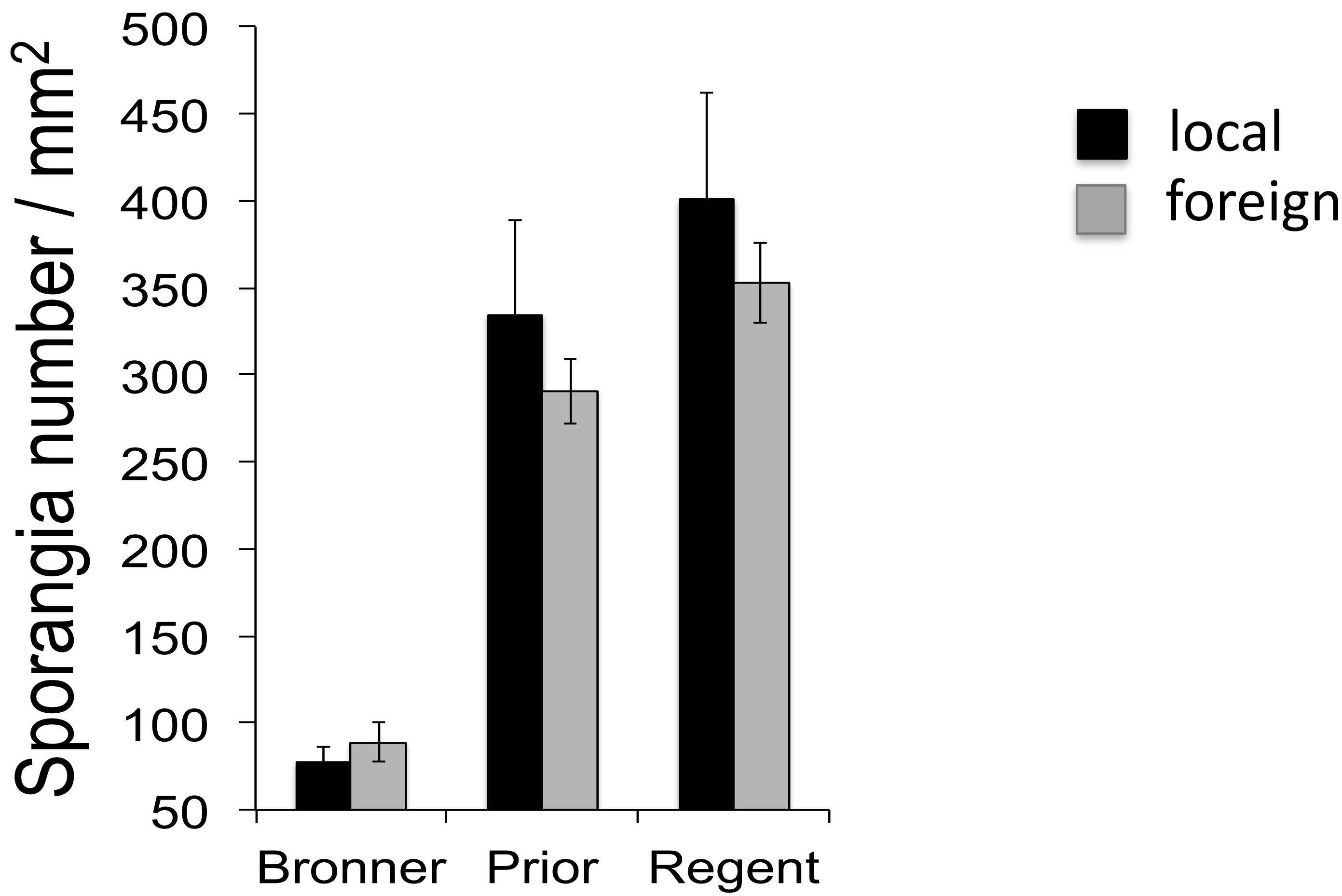
ORIGINAL ARTICLE

Adaptation of a plant pathogen to partial host resistance: selection for greater aggressiveness in grapevine downy mildew

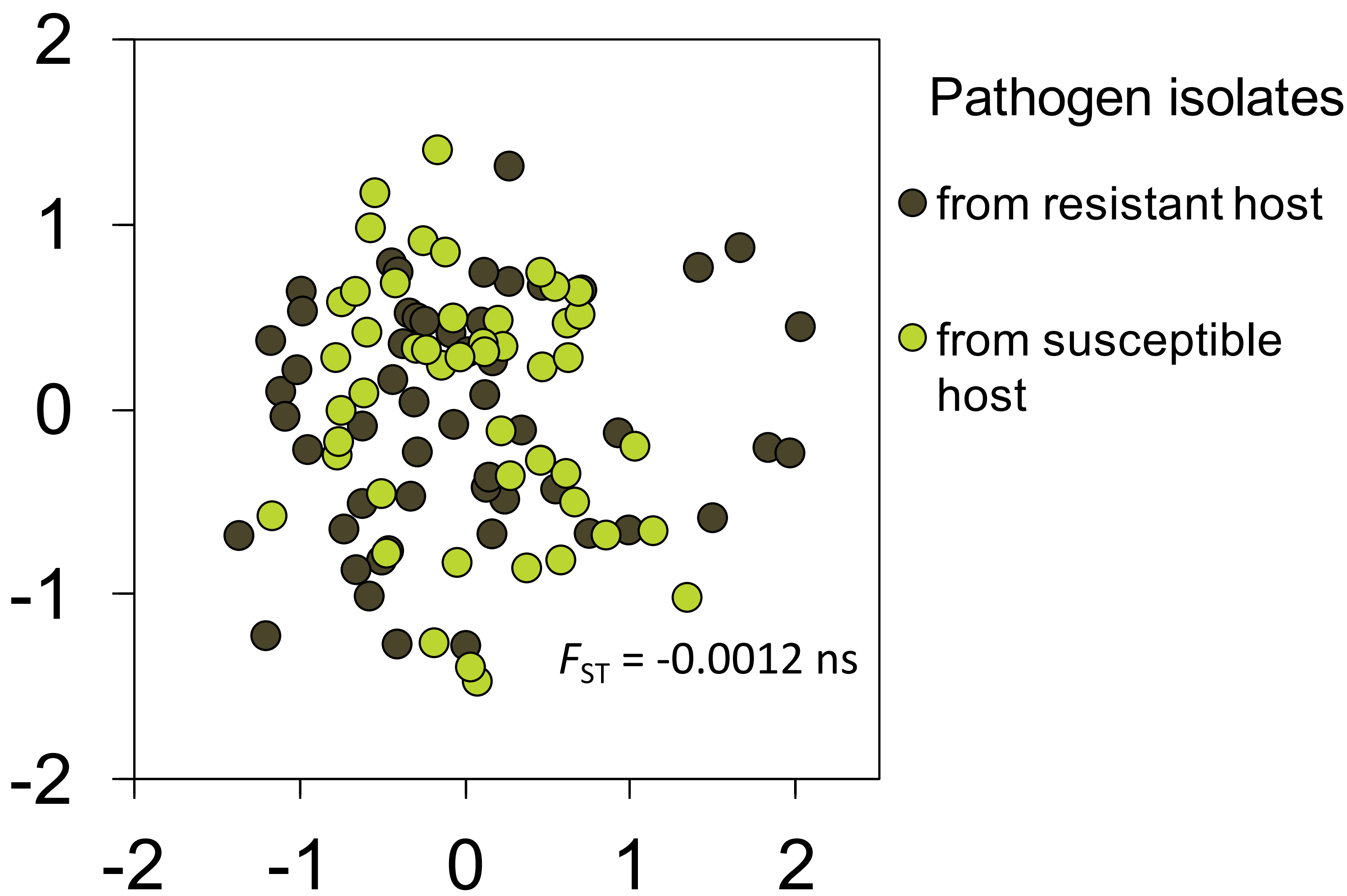
Chloé E. L. Delmas,[1,2] Frédéric Fabre,[1,2] Jérôme Jolivet,[1,2] Isabelle D. Mazet,[1,2] Sylvie Richart Cervera,[1,2] Laurent Delière[1,2] and François Delmotte[1,2]

1 UMR 1065 Santé et Agroécologie du Vignoble, INRA, Villenave d'Ornon, France
2 Bordeaux Science Agro, UMR 1065 SAVE, ISVV, Université de Bordeaux, Villenave d'Ornon, France

Cultivar specificity ?
A general increase of aggressiveness

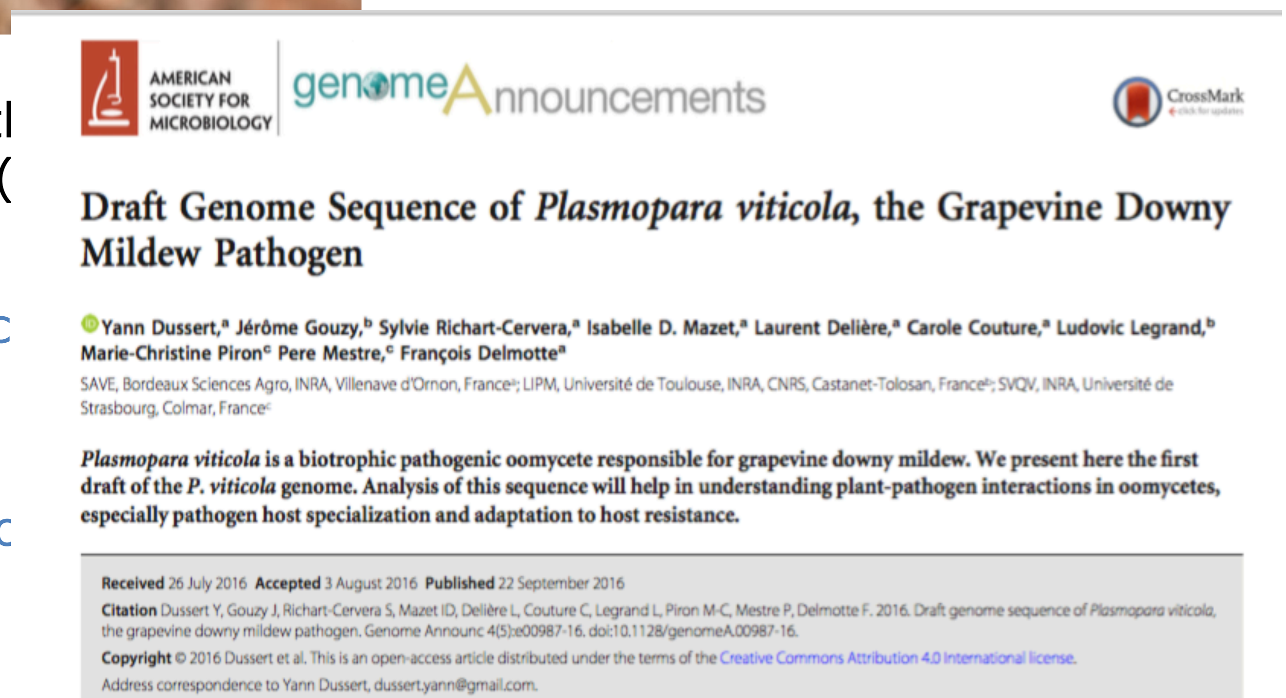


All *P. viticola* isolates were distincts and we found no genetic differentiation between naïve and adapted isolates



What are the *genes* responsible in the erosion of resistance ?

- 2016 : Release of tl
  genome sequence (
  Pv221)
- Population genomic
  by resequencing *P.*
  isolates
- Design molecular tc



AMERICAN SOCIETY FOR MICROBIOLOGY genomeAnnouncements CrossMark

Draft Genome Sequence of *Plasmopara viticola*, the Grapevine Downy Mildew Pathogen

Yann Dussert,[a] Jérôme Gouzy,[b] Sylvie Richart-Cervera,[a] Isabelle D. Mazet,[a] Laurent Delière,[a] Carole Couture,[a] Ludovic Legrand,[b] Marie-Christine Piron[c] Pere Mestre,[c] François Delmotte[a]

SAVE, Bordeaux Sciences Agro, INRA, Villenave d'Ornon, France[a]; LIPM, Université de Toulouse, INRA, CNRS, Castanet-Tolosan, France[b]; SVQV, INRA, Université de Strasbourg, Colmar, France[c]

Plasmopara viticola **is a biotrophic pathogenic oomycete responsible for grapevine downy mildew. We present here the first draft of the** ***P. viticola*** **genome. Analysis of this sequence will help in understanding plant-pathogen interactions in oomycetes, especially pathogen host specialization and adaptation to host resistance.**

Received 26 July 2016 **Accepted** 3 August 2016 **Published** 22 September 2016

Citation Dussert Y, Gouzy J, Richart-Cervera S, Mazet ID, Delière L, Couture C, Legrand L, Piron M-C, Mestre P, Delmotte F. 2016. Draft genome sequence of *Plasmopara viticola*, the grapevine downy mildew pathogen. Genome Announc 4(5):e00987-16. doi:10.1128/genomeA.00987-16.

Address correspondence to Yann Dussert, dussert.yann@gmail.com.

CROPPING SYSTEM – Combine practices (fungicides, agronomical) to :

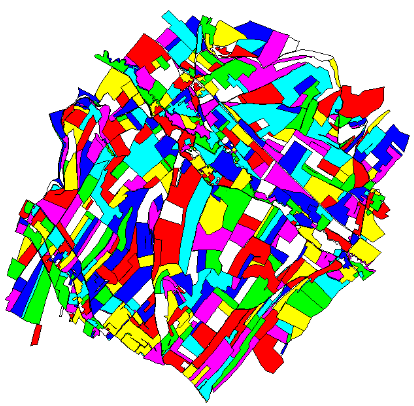
- limit the adaptation of pathogen pops complete resistance efficacy in order to secure the production
- control the pathogens that are not targeted by resistance (i.e. black rot)

Infection efficiency

$$\Psi(x) := \frac{\beta(x)}{\delta}\int_0^\infty r(a,x)\, e^{-\mu a}\,\mathrm{d}a$$

$$r(a,x) := p(x)\chi_{[\tau(x),\tau(x)+i(x)]}(a)$$

Sporulation rate — Latent period — Infectious period



MODELLING - How to deploy resistance ?

: How do pathogen THV impact the erosion of resistance?

- How the connectivity of the landscape affect erosion of resistance ? Compare strategies : stacking, cv mixture?

Achieve durable management of resistant varieties

- Plant resistance is a promising solution to decrease the dependancy to fungicides.
- R-genes constitute a finite ressource (11 locus for PM / 14 locus for DM).
- This ressource is a common good that have to be preserved since it is limited.
- The « community » has to manage this ressource in a non-selfish manner, if we want to avoid the collapse of the system.

This work has been funded by :

RÉGION AQUITAINE

AGENCE NATIONALE DE LA RECHERCHE
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