EUFRAS
EUROPEAN FORUM FOR AGRICULTURAL AND RURAL ADVISORY SERVICES

Collaborative Online Forum For Exchange & Engagement

in collaboration with three viticulture research projects on the topic

"Breeding Resilient Grapevines: From Genes to IPM Solutions"

speakers:

- **Komlan Avia** (INRAE research center of Colmar, France)
- **Soon Li Teh** (University of Minnesota)
- **Giorgio Gambino** (*The Institute for Sustainable Plant Protection of the National Research Council of Italy (CNR-IPSP))*

moderator:

- Anita Dzelme (EUFRAS)

grapebreed 4 IPM

VitisGenIII

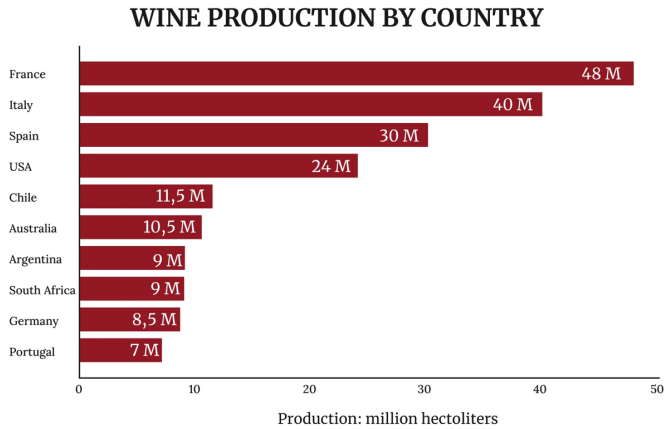
Shield4Grape

Grapevine & Viticulture

- **Grapevine** (*Vitis* spp) a major **economically important** fruit crop worldwide
- Domesticated grapevine (*Vitis vinifera*) is not only economically but also **culturally important**, especially in the EU
- *Vitis vinifera* has **~ 6000 varieties** estimated in the world covering **~ 7.3 Mha with 45% in the EU** (OIV 2024)

Table 1 • Vineyard surface area of major vine-growing countries[3]

kha	2022	2023 Prov.	2024 Prel	24/23 % var.	2024 % world
Spain	955	945	930	-1.5%	13.1%
France	796	788	783	-0.7%	11.0%
China	758	*756*	*753*	-0.4%	10.6%
Italy	718	723	728	0.8%	10.3%
Türkiye	413	406	402	-1.0%	5.7%
USA	391	388	*385*	-0.7%	5.4%
Argentina	207	205	200	-2.4%	2.8%
Romania	188	187	187	0.1%	2.6%
India	175	182	*185*	1.8%	2.6%
Portugal	193	182	173	-5.1%	2.4%



(OIV, 2024)

Viticulture: current challenges

Two major challenges currently:

- **Push to reduce the use of PPP**: heavily used to protect vineyards against multiples pathogens, especially PM and DM

In Europe 2/3 of all fungicides used are applied in viticulture which constitutes only ~ 4% of the agricultural area (Eurostat, 2007)

- **Climate change**: overall increase in temperature, new pests and diseases' pressure, extreme climatic events, higher frequency of abiotic stresses

  → Impact on wine quality and style, shift in the winegrowing areas

Grapevine: current challenges

One of the solutions to those main challenges:

→ Breeding for new grapevine varieties carrying resistance againt main diseases and at the same time adapted to current environmental conditions

The three speakers today will present 3 projects funded embarked in breeding programs aiming at providing solutions to winegrowers

grapebreed 4 IPM

VitisGenIII

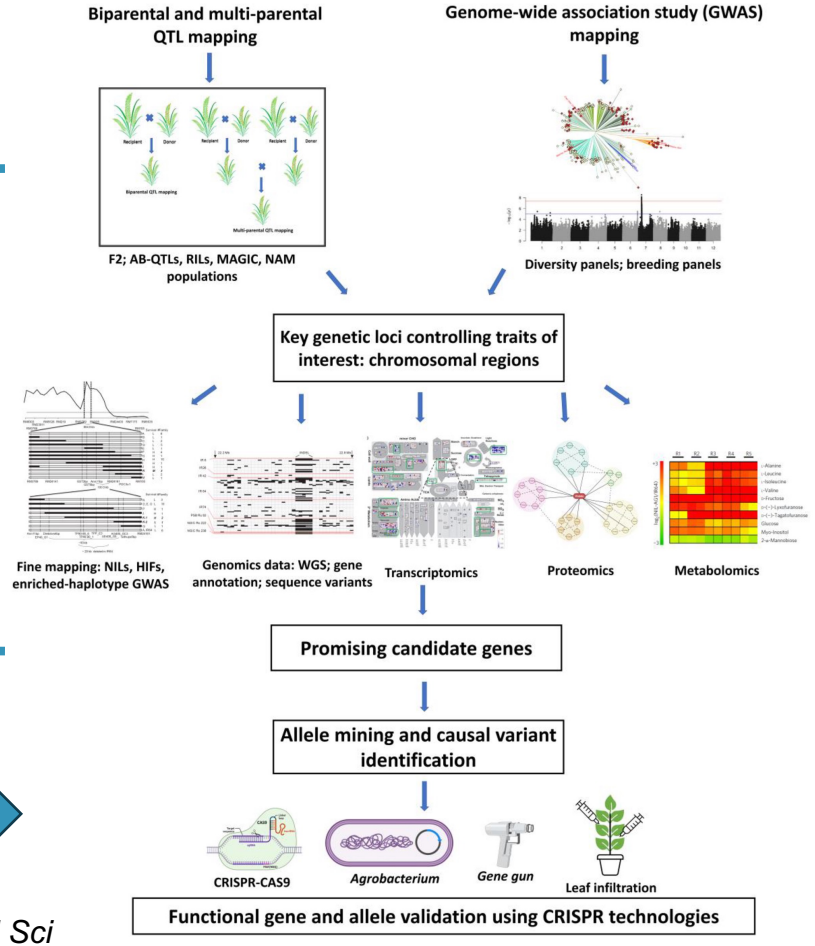
Shield4Grape

Breeding: what do we need?

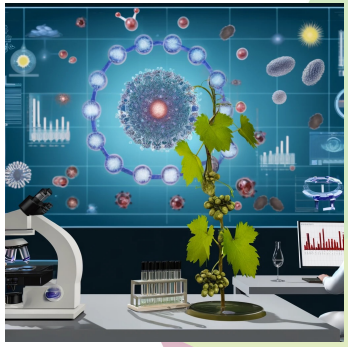
Genetic determination of agronomic and quality traits

Conventional breeding

- Trait phenotyping
- Marker-Assisted Selection
- Genomic selection



NGT-based breeding



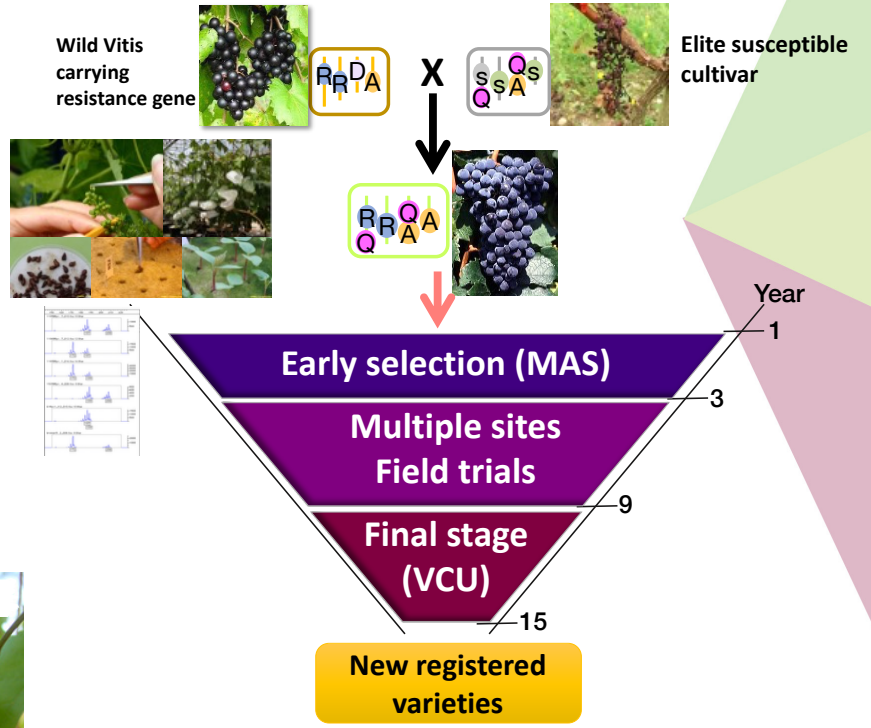
Thomson et al 2022 Int J Mol Sci

Breeding: what do we need?

Genetic determination of agronomic and quality traits

Conventional breeding

- Marker-Assisted Selection
  simple genetic architectures
  (e.g. disease résistance)



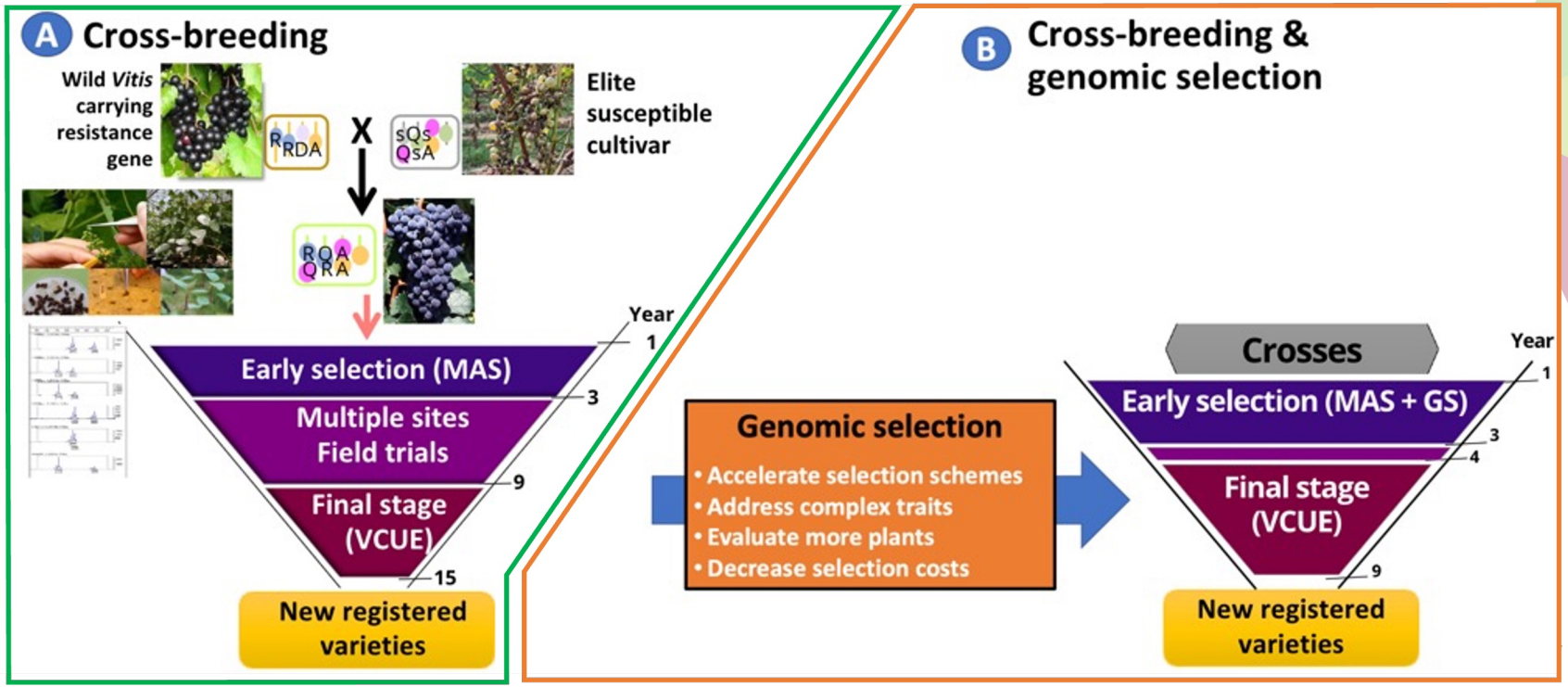
! Disease resistance not only allows to use less pesticide but also to combat some diseases without any protection solutions

Breeding: what do we need?

Genetic determination of agronomic and quality traits

Conventional breeding

- Genomic selection: complex genetic architectures (e.g. abiotic stresses)



Breeding for IPM

IPM: Integrated Pest Management

Based on a diversity of pest management measures (prevention, non-chemical control, best practices for optimizing pesticide efficiency, etc.)

Reduce reliance on pesticides, protect people's health and the environment, promote biodiversity

Best practice guide for DRV cultivation, promote alternative plant protection strategies as low- residue or organic, nourished by decision support systems (DSS): elicitors, resistance inducers, SynComs, green chemistry products

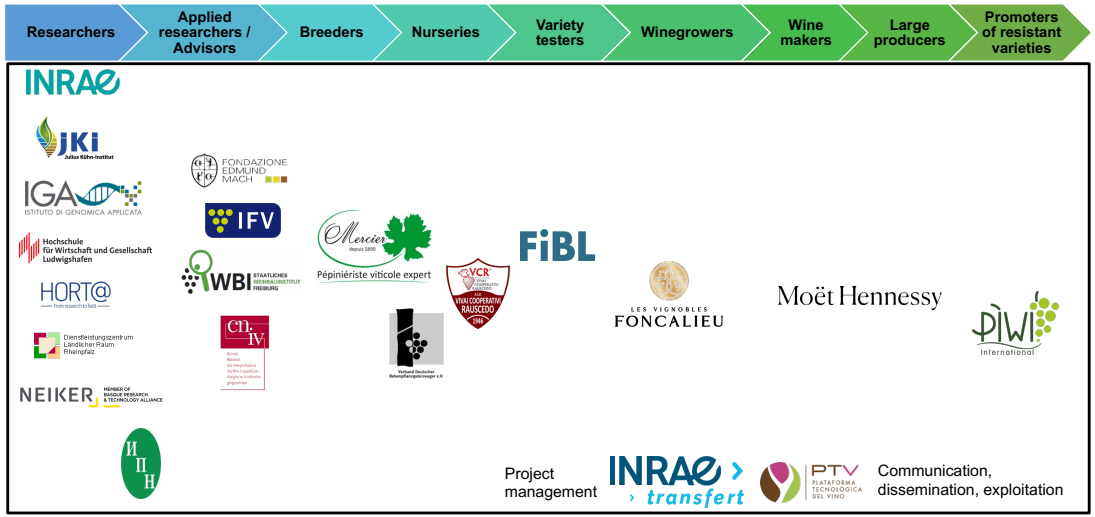
Results of ongoing work on adapted IPM solutions to DRVs to be presented next time

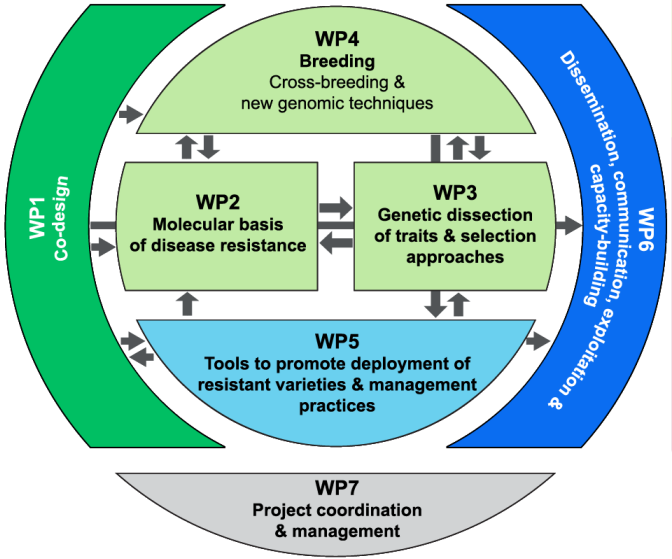
GrapeBreed4IPM

19 partners, 2 associated partners, 7 european countries

5 M€ from the EC and 600 K€ from Swiss gouvernment

4 years (2024-2028)





Outcomes : Disease Resistant Varieties

- Numerous initiatives in Europe, the United States, and globally are dedicated to creating grapevine varieties resistant to diseases and abiotic stresses, while simultaneously investigating pathogen population dynamics

- Some European recent DRVs (or PIWIs): ***Artaban, Floreal, Artys,Opalor, Cabernet Cortis, Solaris, Souvignier gris, Soreli, Fleurtai, Merlot Khorus, …***

- ***More to come…***

- Available from nurseries, who can provide technical info or put in contact with breeders

Outcomes : Disease Resistant Varieties

- DRVs or PIWIs must be considered fragile common goods, as their resistance factors remain inherently vulnerable to breakdown

- To safeguard their effectiveness and ensure long-term durability, they require a minimal yet consistent level of crop protection (at least two treatments around the flowering period) and should be managed with the same care as emblematic grapevine varieties

A push from regulatory changes: DRVs in PDOs

- DRVs need time to establish themselves and deliver their full impact in line with the EU Green Deal objectives

- Regulatory adjustments are also required to accelerate their adoption, particularly their integration into Protected Designations of Origin (PDOs), which play a central role in structuring the wine industry in several countries

- In France, since 2023, DRVs may be planted on up to 5% of a given vineyard, and their wines can account for up to 10% of a blend while still retaining the appellation status

The Voltis variety is now included in the specifications of the Champagne PDO

COMITÉ CHAMPAGNE

Tracking the durability of the resistance factors

Extending a French initiative to European level

Observatoire national du déploiement des cépages résistants

Oscar·EU
European Observatory for the Deployment of Disease Resistant Grapevine Varieties

INRAE IFV FFPV cn.IV AGRICULTURES & TERRITOIRES CHAMBRES D'AGRICULTURE

Observatory Network

Knowledge aquisition

- ***Effectiveness of varieties***
- ***Variability depending on pest/disease pressure and management strategies***
- ***Emergence of sanitary issues***
- ***Frequency of virulence alleles***

Alert System

Identification of issues

- ***Characterization of pathogen populations***
- ***Measures to be taken***

https://observatoire-cepages-resistants.fr/en/

Disease Resistant Varieties outside Europe

Focus on one of the major initiative in the US : the VitisGen project

→ **Dr. Soon Li Teh**

*Vitis*Gen – project summary

- 14 years, $20.5M, 65 scientists, 20 institutions
- Focus: Apply technological innovations to deliver breeding lines with durable powdery mildew resistance & high fruit quality, and to better manage existing vineyards


Selma Pete


Arandell


Marquette


Aromella


DOVine

Value of powdery mildew resistance

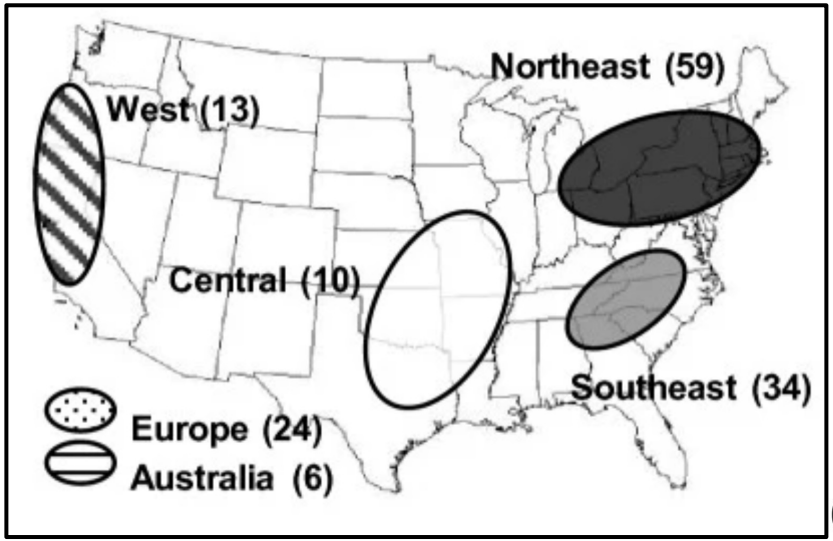
Projected benefits of adopting PM resistant vines in California raisin grapes

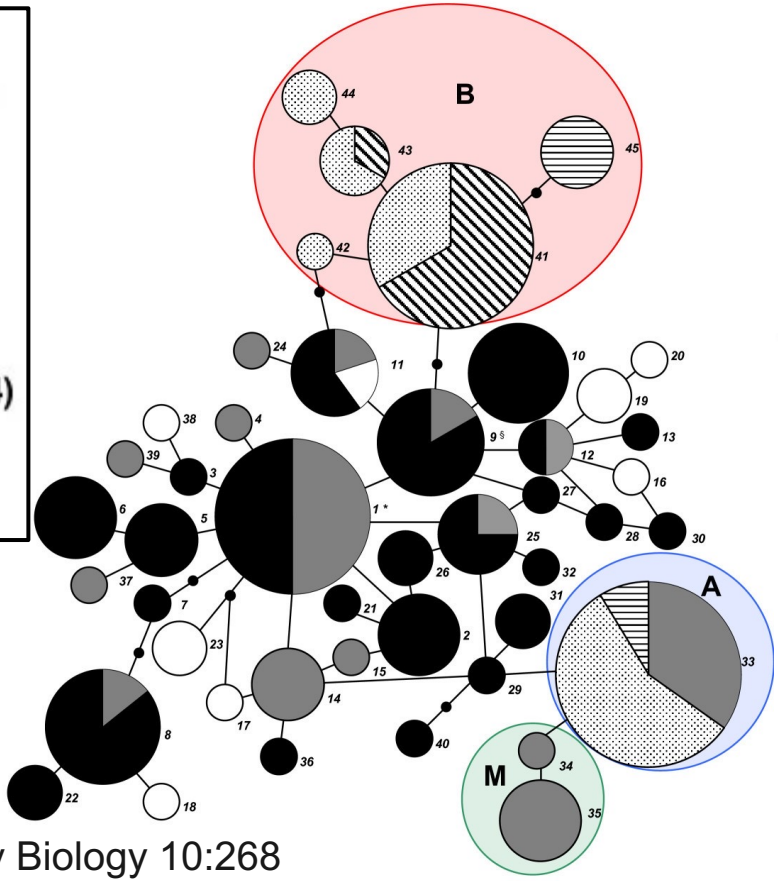
Adoption rate	Adoption lag (years)			
	10	20	30	40
20%	$124M	$92M	$69M	$51M
60%	$372M	$277M	$206M	$153M
100%	$620M	$461M	$343M	$255M

Fuller et al. (2014) Wine Economics & Policy 3:90-107

****Economic incentive to accelerate and increase adoption****

Pathogen genetics informs host genetics





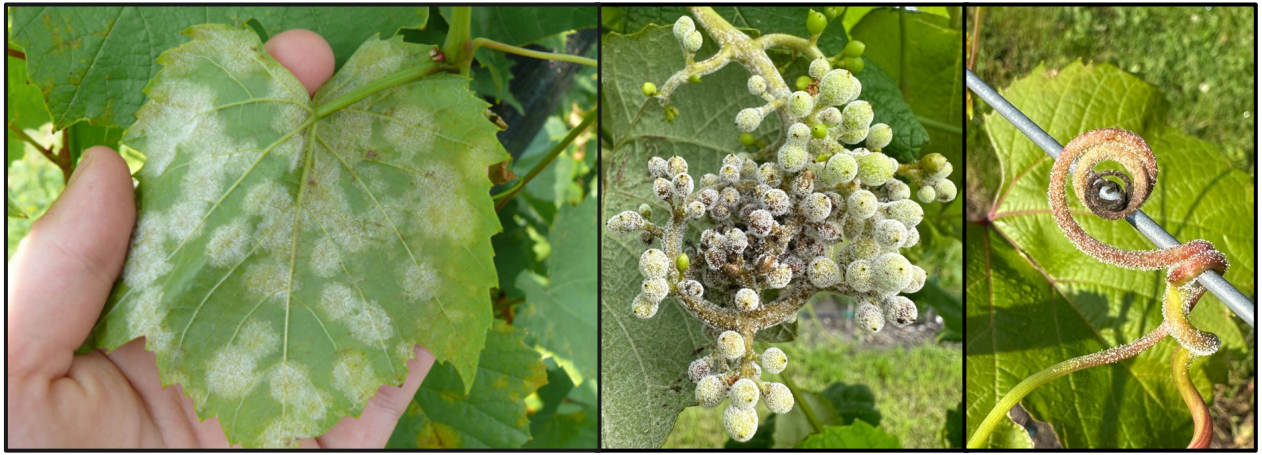
Brewer & Milgroom (2010) BMC Evolutionary Biology 10:268

Powdery mildew resistance in U.S. grape breeding

	Locus	Chr	*Vitis* source	Race-specific	Reference
Strong	***Run1***	**12**	***rotundifolia***	**Yes**	**Feechan et al. 2013**
	Run2.1	18	*rotundifolia*	Yes	Ramming et al. 2012
	Ren1	13	*vinifera*	Yes	Hoffman et al. 2008
	Ren2	14	*cinerea*	Yes	Cadle-Davidson et al. 2016
	Ren3/9	15	*complex*	Yes	Welter et al. 2007
Strong	***Ren4***	**18**	***romanetii***	**?**	**Ramming et al. 2011**
Strong	***Ren6***	**9**	***piazeskii***	**Yes**	**Pap et al. 2016**
	Ren7	19	*piazeskii*	nd	Pap et al. 2016
	Ren10	2	*complex*	nd	Teh et al. 2017
	Ren11	15	*aestivalis*	Yes	Karn et al. 2021
Strong	***Ren12***	**13**	***amurensis***	**nd**	Sapkota et al. 2023
	Ren13	9	*aestivalis*	nd	Sapkota et al. 2025
	Sen1	9	*vinifera*	nd	Barba et al. 2014
	Sen2	7	*complex*	nd	Duwadi et al. 2025

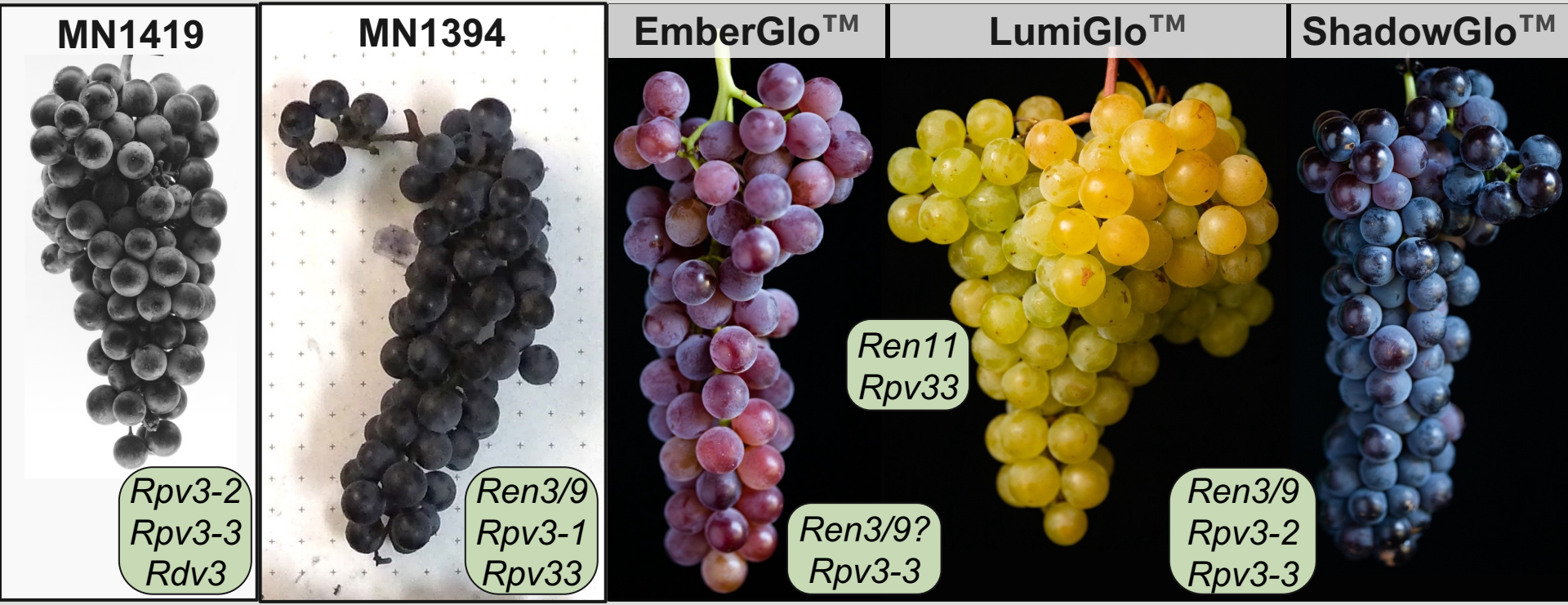
Downy mildew resistance in U.S. grape breeding

Locus	Chr	*Vitis* source	Race-specific	Reference
Rpv1	**12**	***rotundifolia***	**?**	
Rpv3-1	18	*complex*	?	
… now we can predict Rpv3-2, Rpv3-3, Rpv10L, ***Rpv10_1eu****, Rpv12-588634, Rpv12-588631,* ***Rpv12_1eu****, Rpv17, Rpv18, Rpv19, Rpv20, Rpv21, Rpv27,* ***Rpv33****, Rpv34, Rpv35*				



We are establishing a new research vineyard of all RPVs in the center of pathogen diversity – for international collaboration.

---------- Wine grapes ---------- | ---------- Seedless table grapes ----------



Zone 3 | ---------- Zone 4 USDA Cold Hardiness ----------

Soon Li Teh

UNIVERSITY OF MINNESOTA

Resistance to:
Powdery mildew (*Run* or *Ren*)
Downy mildew (*Rpv*)
Phylloxera (*Rdv*)

Teinturier

Juice grape

NY06.0514.06

Run1
Ren2
Ren3/9
Rpv1
Rpv3-1

NY10.0925.02

Run1
Ren2
Rpv1
Rpv3-1

NY14.0304.03

Run1
Ren2
Ren3/9
Rpv1
Rpv3-1

NY15.0406.03

Run1
Ren2
Ren3/9
Rpv1
Rpv3-1

NY15.0403.01

Run1
Ren2
Ren3/9
Rpv1
Rpv3-1

Madeline Oravec

Cornell University®

Resistance to:
Powdery mildew (*Run* or *Ren*)
Downy mildew (*Rpv*)

Camminare Noir

- Early dormancy break
- Early bloom & ripening

Paseante Noir

- Relatively late bloom
- Mid-season ripening

Errante Noir

- Mid-season bloom
- Mid-season ripening

Ambulo Blanc

- Early bloom & ripening

Caminante Blanc

- Relatively late bloom
- Mid-season ripening

---------- Highly resistant to Pierce's disease ----------

Luis Diaz-Garcia

UC DAVIS
UNIVERSITY OF CALIFORNIA

How can we also improve traditional varieties?

Insights from another Horizon Europe project: **Shield4Grape**

Dr. Giorgio Gambino

Shield4Grape

16 partners from **7** Countries

The consortium is interdisciplinary, multi-actor, cross-border, collaborative and well representative of different EU biogeographical regions and it knows the local requirements.

Start **February 1, 2024**

Externally supported by the **International Organisation of Vine and Wine (OIV)**

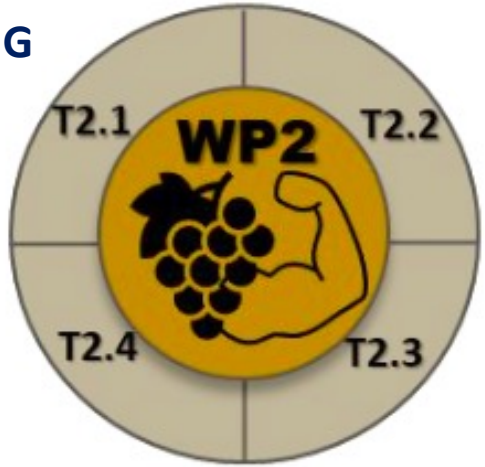
OIV International Organisation of Vine and Wine
Intergovernmental Organisation

Shield4Grape exploits different genetic improvement techniques

The aim is to develop **new grapevine varieties** with **improved tolerance/resistance to relevant fungal diseases** and **adapted** to local environmental and pedo-climatic conditions

➢**CONVENTIONAL BREEDING**
Marker-Assisted Selection

protection of EU regions interested by high-pressure of PM and DM



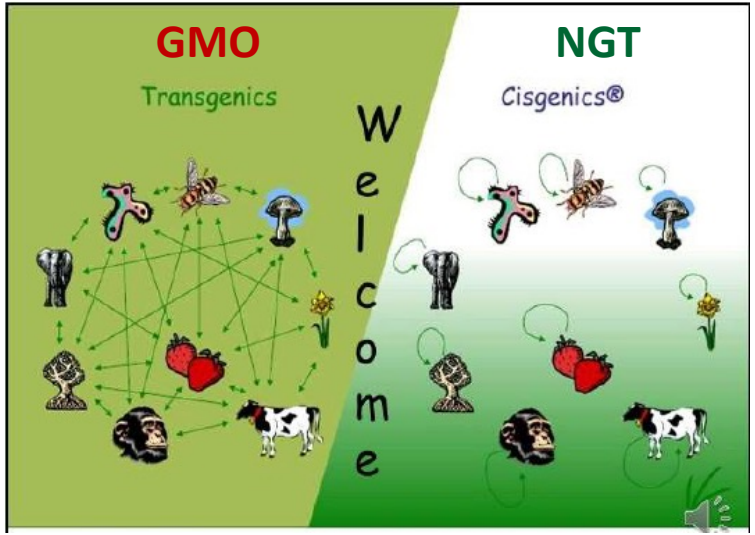
➢ **New genomic techniques_ NGTs**
No GMO!

CISGENESIS
GENOME EDITING

protection of EU heritage of traditional grape varieties (unique vine-terroir combinations)

➢**SOMACLONAL VARIATION**
No GMO!

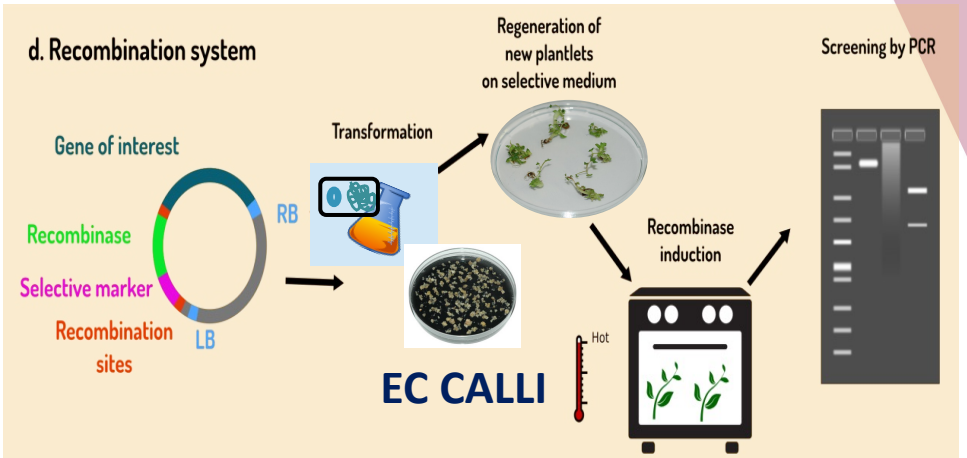
NGTs: Cisgenesis



Transfer of a complete gene between varieties of the same species or interspecific species

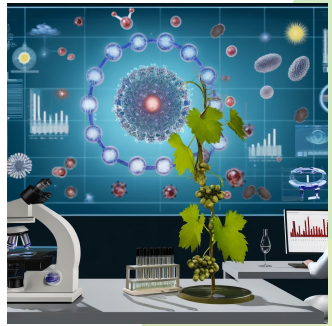
Mirroring the transfer of a gene that would occur naturally with a conventional breeding

V. quinquangularis —(genetic trait for abiotic/biotic tolerance)→ ***V. vinifera***



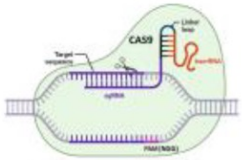
Absence of DNA not belonging to the Vitis genus (antibiotic/herbicide resistance genes)

NGTs: Genome editing



Genome editing refers to the set of techniques that allow for the targeted modification of specific genes by inducing cuts in the double strand of DNA, which are then repaired.

J. Doudna e E. Charpentier
2020 Nobel Prize in Chemistry



CRISPR-CAS9

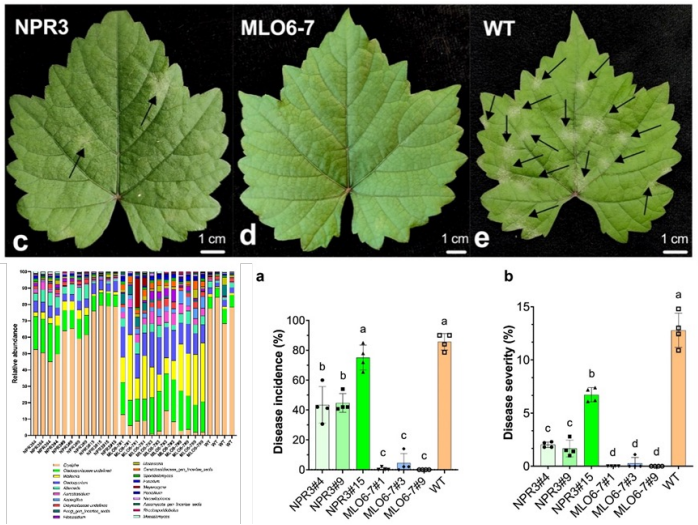
The genotypes produced through genome editing are variants of traditional grape varieties, indistinguishable from the mutations that can occur spontaneously in nature and that have given rise to the clones currently available on the market. No new DNA sequences are inserted.

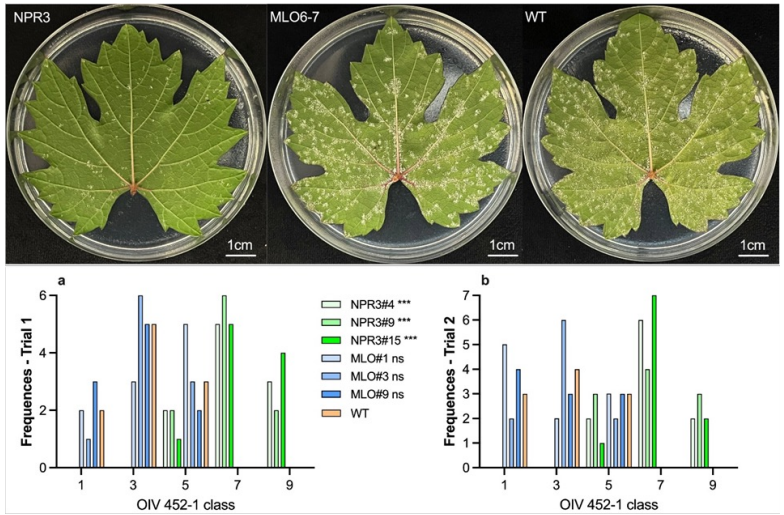
Application of genome editing to improve grape stress resilience I

Traditional variety: **Chardonnay**

VvMLOs-edited plants displayed a quasi-complete **resistance to *Erysiphe necator***.

VvNPR3-edited plants displayed improved resilience to **both *Erysiphe necator* and *Plasmopara viticola***.



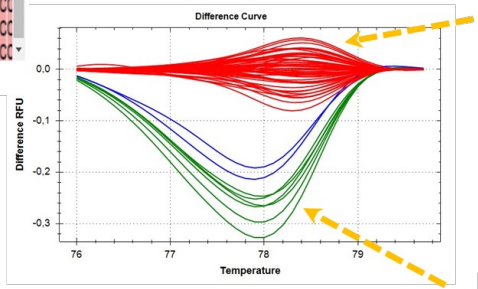


Application of genome editing to improve grape stress resilience II

Traditional variety: **Nebbiolo**

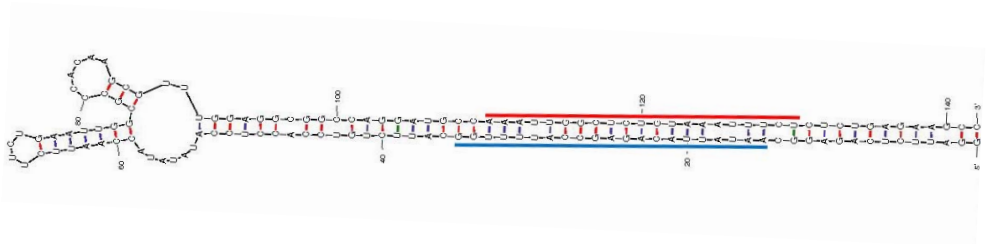
mir482-edited plants displayed a potential broad-spectrum tolerance to different pathogens

PCR *High Resolution Melting analysis*



Nebbiolo mother plant + unedited Nebbiolo plants

Edited Nebbiolo Plants



Are NGT plants ready for the vineyard?

- ✓ **In the coming years, several traditional cultivars will be improved through genome editing: Chardonnay, Nebbiolo, Merlot, Cabernet Sauvignon, Barbera, Glera, Sangiovese, Pinot noir, etc….BUT**
- ✓ **Restrictions on field trials in Europe:**

  NGT plants are currently still subject to the existing European framework governing traditional genetically modified organisms (GMOs)

- 5 July 2023, the EU Commission tabled a proposal for a regulation on NGTs.
- 7 February 2024, the EU Parliament adopted its first-reading position.
- 8 April 2025, the European Parliament's Committee on Environment, Food Safety and Public Health (ENVI) voted in favor of opening interinstitutional negotiations among the Commission, Parliament and Council.
- The EU is now considering the introduction of a differentiated risk assessment for genome-edited plants (edited plants of the NGT-1 category considered equivalent to conventional plants), acknowledging that these techniques may not necessarily pose the same environmental and health risks as traditional GMOs.
- The revisitation of the legislative framework regarding NGTs could be pivotal in accelerating technical advancements in grapevine improvement.

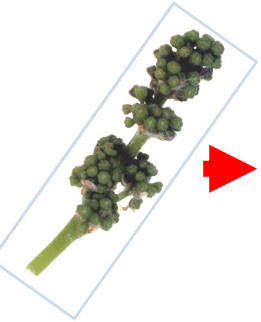
SOMACLONAL VARIATION

✓**SOMATIC EMBRYOGENESIS**: development of embryos from plant somatic tissues

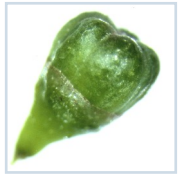
✓**SOMACLONES**: vine plants obtained through somatic embryogenesis

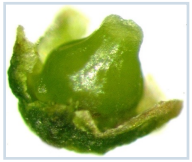
✓**SOMACLONAL VARIABILITY**: **genetic variability** resulting from gene mutations and/or epigenetic changes that naturally occur during regeneration by somatic embryogenesis, and which **can be exploited**, in addition to traditional breeding purposes, also **to select genotypes with greater resistance to biotic and abiotic stresses.**

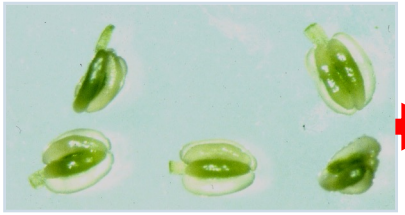
Plant regeneration via somatic embryogenesis

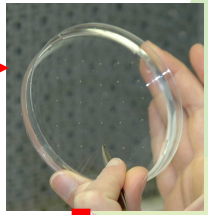


immature inflorescences

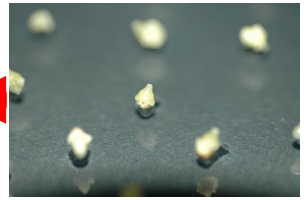


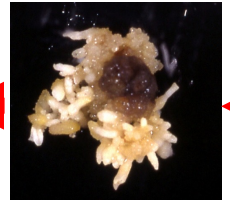


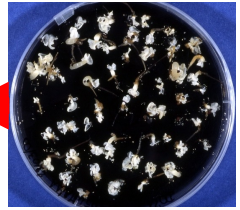




in vitro culture in calli induction medium







Somaclone regeneration

Somaclones in field

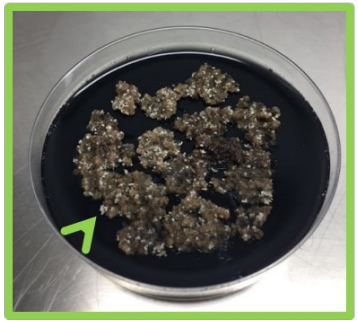
Somaclonal variation to produce mutants resilient to different environmental conditions

PRIMED SOMACLONES

Vitis vinifera / rootstocks

Resistance inducer

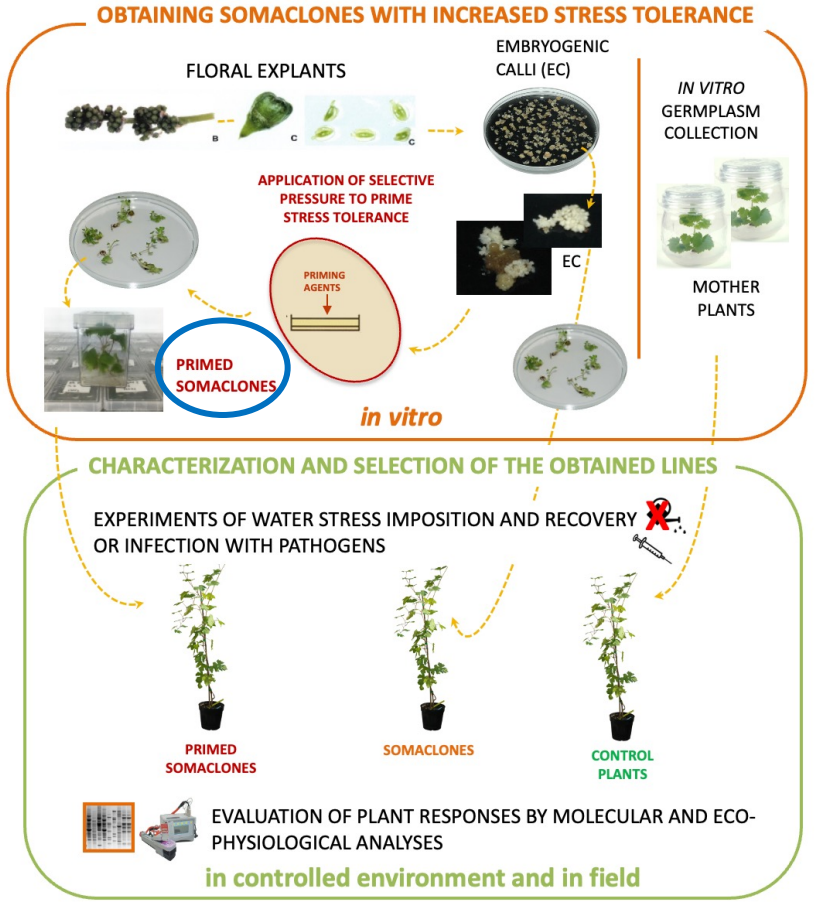
activator of plant defense mechanisms effective in increasing resistance to fungi



PEG8000- polyethylene glycol

A polymer that cannot be metabolized by plant cells and that simulates water shortage conditions in vitro

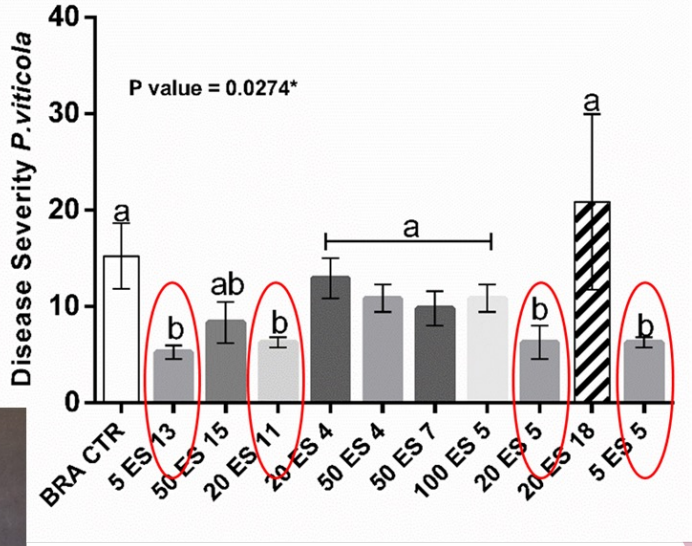
In vitro application of a **selective pressure** favor the regeneration of somaclones with **increased tolerance/resistance** to abiotic and biotic stresses



New somaclones with improved tolerance to biotic stresses

Bragat rosa

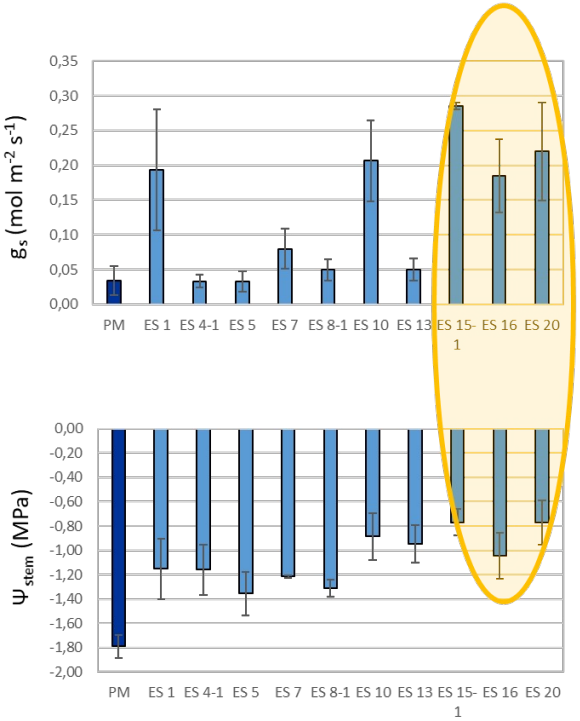
Resistance inducer



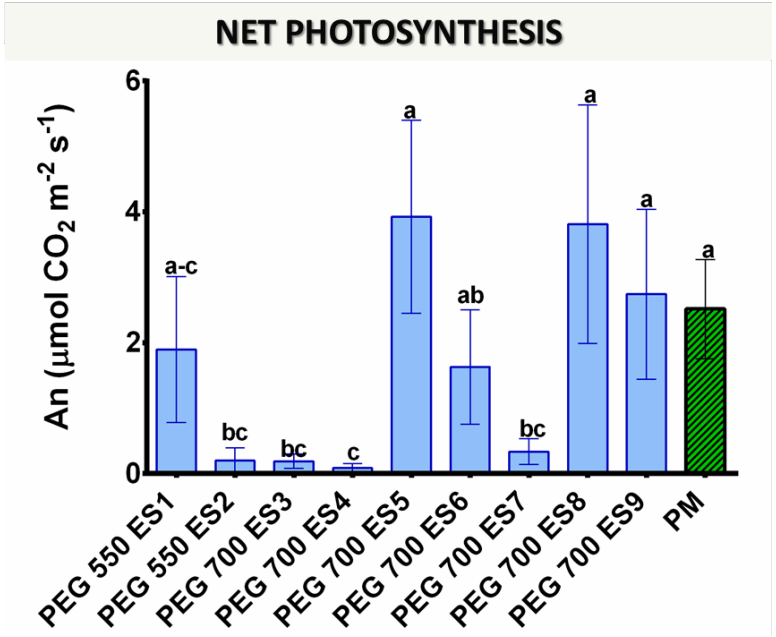
Reduction in disease severity by 50%

New somaclones of V. vinifera cv Nebbiolo with improved tolerance to drought

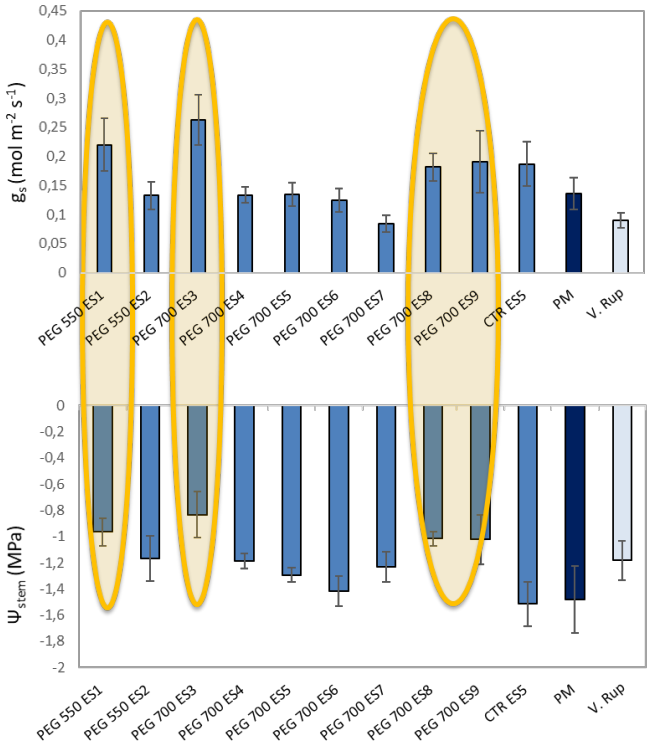
Stomatal conductance (g_s) and water potential (Ψ) **after 15 days of water stress**



New somaclones of rootstock 110R with improved tolerance to drought



Stomatal conductance(gs) and stem water potential (Ψ) on August, 22 2023 (**under drought conditions**)



New somaclones ready for the vineyards

Somaclones in field in Italy: 110R, Nebbiolo, Chardonnay, Dolcetto, Moscato bianco, Cabernet Sauvignon, Sangiovese, Bragat rosa

New somaclones ready in 2026: Chardonnay, Barbera, Pinot noir, Amur Seedless, Pinot Regina, Graciano, Tempranillo, Fernão Pires, Castelão, Touriga Franca, Zenit, Kadarka

DRVs *vs* NGTs *vs* SOMACLONES

DRVs	NGTs	SOMACLONES
New varieties with potential changes in organoleptic quality in respect to parental V. vinifera lines	**Traditional grape varieties** are maintained and the identity of the wines should be preserved → field trials needed	**Traditional grape varieties** are maintained and the identity of the wines should be preserved → field trials ongoing
Long breeding cycles (12-15 years)	Reduced breeding time (5-8 years)	Reduced breeding time (5-8 years)
Insertion of **specific resistance genes to specific pathogens**. Possibility to combine interesting traits (resistance, productivity, quality..)	Possibility of inducing a broader spectrum tolerance towards different pathogens	Possibility of inducing a **broader spectrum tolerance towards different pathogens** and/or a multistress tolerance
Prior knowledge of the genetic basis of the trait of interest is needed	Prior knowledge of the genetic basis of the trait of interest is needed	Prior knowledge of the genetic basis of the trait of interest is not required
Poor knowledge of genetic traits associated with different biotic and abiotic stress tolerance	Poor knowledge of genetic traits associated with different biotic and abiotic stress tolerance	Useful for those traits relying on complex genetic bases and highly influenced by environmental conditions, such those associated with abiotic stress tolerance
Subjected to a regulatory framework (Protected Designation of Origin)	**Waiting for the forthcoming revision of EU legislation** which will regulate the use of NGT products	**No limits imposed by current legislation**: new genotypes can be transferred to the vineyard as traditional clones

Take-Home Messages

✓**European viticulture must start exploiting the new opportunities of genetic improvement to be more sustainable and meet the European Green Deal objectives (50% reduction of pesticides by 2030)**

Grapevine is one of the very few crop species where genetic improvement has not had a significant impact on the crop. The genotypes cultivated today were selected hundreds of years ago under completely different climatic conditions and pathogen pressure.

✓**There is no single best approach to grapevine genetic improvement, their use often depends on socio-cultural background of grape-growing areas**

DRVs: new genotypes, restriction in PDO – protected designation of origin, not all European countries have made the appropriate legislative changes

NGTs: traditional genotypes, restriction to GMO legislation

✓**There is not and there will never be a 'SUPER VINE' resistant to all diseases and all environmental stresses**

All improved genotypes always require a minimum number of treatments against PM and DM during the season.

✓**For a resilient viticulture, the new genotypes should be accompanied by effective vineyard management and IPM strategies for the new genotypes**

Follow us

VitisGen3 https://vitisgen3.umn.edu/

GrapeBreed4IPM https://grapebreed4ipm.com/
https://www.linkedin.com/company/grapebreed4ipm-eu-project/

Shield4Grape https://shield4grape.eu/
https://www.linkedin.com/company/shield4grape-project/

THANK YOU!

EUFRAS European Forum for Agricultural and Rural Advisory Services – Collaborative Online Forum For Exchange & Engagement

grapebreed 4 IPM

VitisGenIII

Shield4Grape

Funded by the European Union

USDA

Project funded by

Schweizerische Eidgenossenschaft
Confédération suisse
Confederazione Svizzera
Confederaziun svizra

Federal Department of Economic Affairs, Education and Research EAER
State Secretariat for Education, Research and Innovation SERI

Swiss Confederation