Grape breeding

High genetic diversity, diploid genomes, and clonal propagation make the creation and maintenance of distinct grapevine varieties genetically and logistically simple.

Grape Breeding Steps

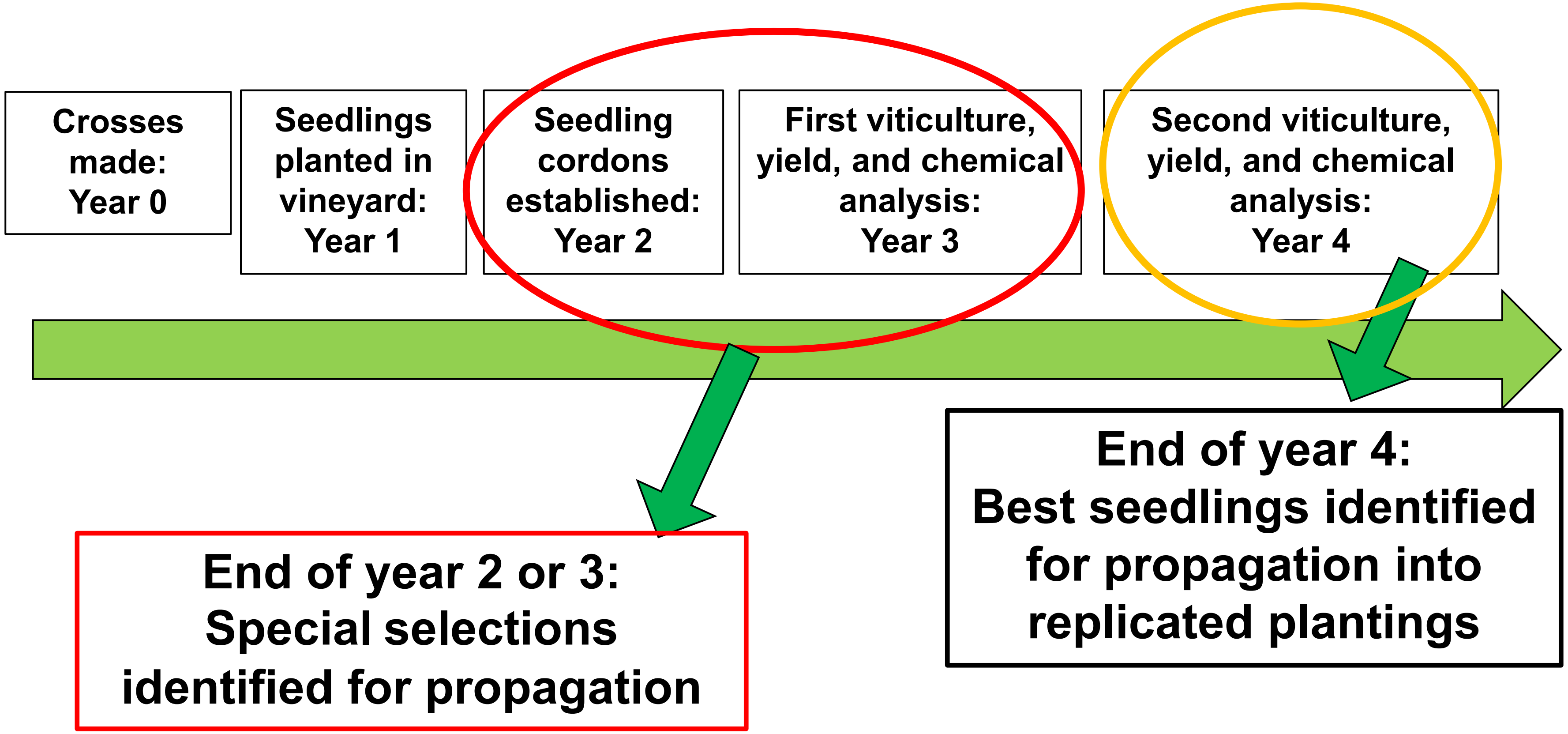
Seedlings in greenhouse

Seedlings in vineyard

Seedlings in fruit

Marker assisted selection for quality and disease resistance

Breeding timeline: Developing and identifying best seedlings



Breeding timeline: Evaluating wine quality

10 vines of each selection established in vineyard (replicated planting): Year 5

Cordon establishment: Year 6

Viticulture observations, including yield. Research wine produced and analyzed: Year 7

Viticulture observations, including yield. Research wine produced and analyzed: Year 8

Viticulture observations, including yield. Research wine produced and analyzed: Year 9

2012 crosses: Earliest planting at 20 acre commercial scale: 2022

After year 9: Best selections commercialized

Susceptible

Resistant

Powdery mildew: *Vitis vinifera* Ren1 genetic resistance

Grape breeding for disease resistance

- Public and private sector efforts
- Powdery mildew and downy mildew resistance are main targets
- Many sources of disease resistance have been identified
- Molecular marker development is expected for new genes
- Coordinated national projects (VitisGen 1, 2, 3) and international cooperation share germplasm, marker information, and evaluation methods

Main barriers to commercialization: lack of quality and yield

WINE COUNTRY

Leafroll and red blotch diseases

- Certification programs and clean plant material are essential in managing leafroll and red blotch diseases

- Leafroll disease is the leading virus disease of grapevine yield and quality loss worldwide
  - Associated viruses have more confirmed vectors than red blotch
  - Highest priority target for grapevine virus resistance exploration research

- Red blotch disease is regionally important

Historical challenges to identifying and deploying grapevine resistance to virus diseases

- Graft inoculation used instead of insect vectors

- Virus detection
  - Biological resistance vs tolerance
- Genetic diversity and population structure of germplasm
  - Dominant vs recessive sources of qualitative resistance
- Breeding timeline
- Breeding methods: grape and wine evaluation

Pierce's Disease Resistant Varieties


Caminante Blanc


Errante Noir

Images courtesy of Andy Walker, UC Davis

Pierce’s Disease Resistant Varieties: Successful Approach of Walker et al., UC Davis

- Diverse germplasm screened effectively in controlled conditions
- Biological resistance identified
- Qualitative resistance mapped
- Molecular markers developed and validated
- Marker assisted selection used to accelerate generations
- Vineyard performance and wine quality evaluation
- Commercialization

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ARTICLE

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A single resistance factor to solve vineyard degeneration due to grapevine fanleaf virus

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Communications Biology 4, no. 1 (2021): 637.

GFLV Resistance
Approach of Djennane et al.

- Seedlings from self-pollination of wine grape varieties evaluated
  - Nematode inoculation
  - Genetic structure of population addresses both dominant and recessive resistance
- Biological resistance identified
- Qualitative resistance mapped
- Molecular markers developed and validated

Next steps:

- Introduce GFLV resistance into rootstock varieties
  - Marker assisted selection to move resistance allele from Riesling through crossing
  - Gene editing or mutagenesis (following gene function confirmation)
- Test and validate improved rootstocks in vineyards
- Commercialization

Table 1 Infection rate of 11 S1 progenies derived from grapevine varieties or *Vitis* species, and the susceptible controls (sc).

Genotype	Plant material origin	Number of analysed plants	% of GFLV positive plants
Cabernet Sauvignon (sc)	Green cuttings	27	100
40024 (sc)	Seed sowing	8	100
S1 Cesar	Seed sowing	56	84
S1 Cot	Seed sowing	9	89
S1 Mauzac	Seed sowing	15	60
S1 Merlot	Seed sowing	26	70
S1 Mondeuse	Seed sowing	14	85
S1 Riesling	Seed sowing	8	0
S1 Tempranillo	Seed sowing	6	100
S1 Uburebekur	Seed sowing	6	100
S1 *Vitis berlandieri*	Seed sowing	4	100
S1 *Vitis lincecumii*	Seed sowing	15	100
S1 *Vitis monticola* large bell	Seed sowing	22	91

The percentage of grapevines infected by GFLV is revealed by DAS-ELISA on leaves, following *X. index*-mediated transmission performed through 24 months of greenhouse cultivation in containers filled with soil naturally contaminated by viruliferous nematodes.

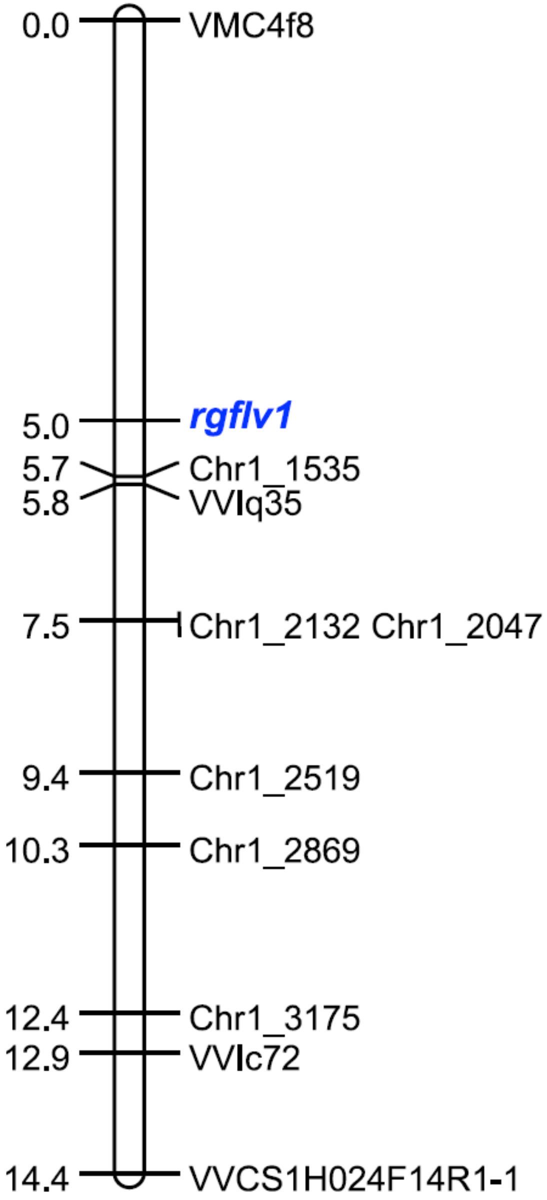

Fig. 5 Genetic map of the *rgflv1* locus. Ten SSR markers located on chromosome 1 and surrounding the *rgflv1* locus are represented. Scale on the left is in cM.

Djennane, Samia, Emilce Prado, Vincent Dumas, Gérard Demangeat, Sophie Gersch, Anne Alais, Claude Gertz, Monique Beuve, Olivier Lemaire, and Didier Merdinoglu. "A single resistance factor to solve vineyard degeneration due to grapevine fanleaf virus." Communications Biology 4, no. 1 (2021): 637.

Vector resistance

- Host plant resistance against some mealybug species is reported in grapevine
- Mealybug species may have multiple hosts and transmit multiple viruses
- Integrated Pest Management approaches and other methods for managing mealybugs are in use
- Poor prospects for managing leafroll disease through host plant resistance

Image from Naegele, Rachel P., Peter Cousins, and Kent M. Daane. "Identification of Vitis cultivars, rootstocks, and species expressing resistance to a Planococcus mealybug." Insects 11, no. 2 (2020): 86.

Exploration for leafroll disease resistance

- Coordinate interdisciplinary research to address widespread and important problem of leafroll disease

- Use important vector insect species for transmitting leafroll associated viruses to test vines under controlled conditions
- Evaluate diverse grape germplasm and grape populations with appropriate genetic structure
- Develop molecular information to support breeding and variety commercialization