XIII. International Symposium on Grapevine Breeding and Genetics
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Vitis Genetic Resources: Current Challenges, Achievements and Perspectives

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Vitis genetic resources (VGR)
Definition and scope

- VRG = Grapevine Germplasm =
  "All plant material of immediate or potential interest for the improvement of grapevine"

- **All taxonomic levels** within *Vitis* genus: subgen. > sp. > subsp. > cv. > clones
- **Wild** and **cultivated** genepools
- **Traditional** varieties and new **elite** cultivars
- Populations, plants, cell cultures, DNA, genes

- Limiting **genetic erosion**
- Fighting grape **diseases**
- Adapting to **climate change**
- Responding to **consumer** and citizen demands
- Now and in the future

- Re-cultivation
- Acclimatization
- Crossbreeding
- Bud sport selection
- Clonal selection
- Biotechnologies

- Wine grapes
- Table grapes
- Rootstocks
- Others

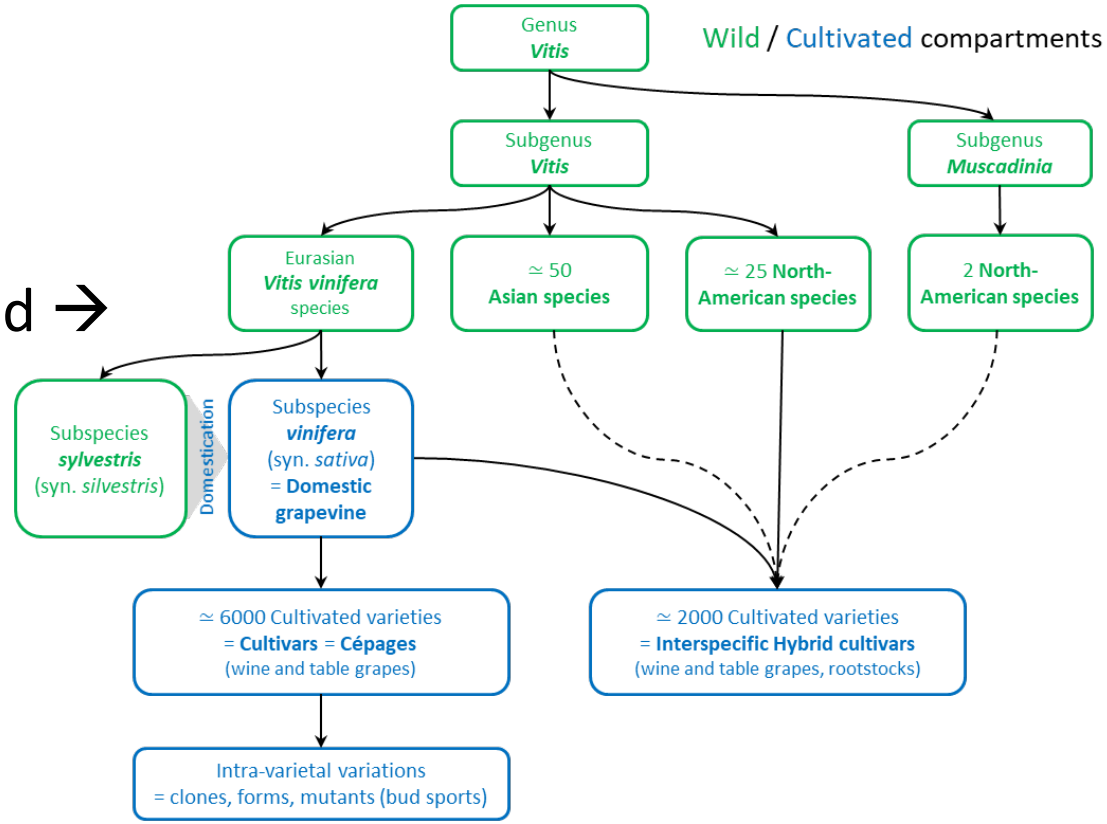
- Field of study and action:

Sources of diversity → **Collecting** → **Conservation** → **Characterization** → **Distribution** → **Uses**

1 Sources of grapevine diversity

Identification and challenges

- Deposits depend on the **taxonomic level** considered →
- **Existing diversity**, resulting from long timespan
  - Natural environment
  - Cultivated environment
    - Ancient vineyards
    - Trellises in gardens
- **New diversity**, recently created
  - Breeders: introgression lines, elite cultivars, pre-breeding genitors
  - Basic research: mutants, transgenic lines, NBT



Sources of grape diversity:

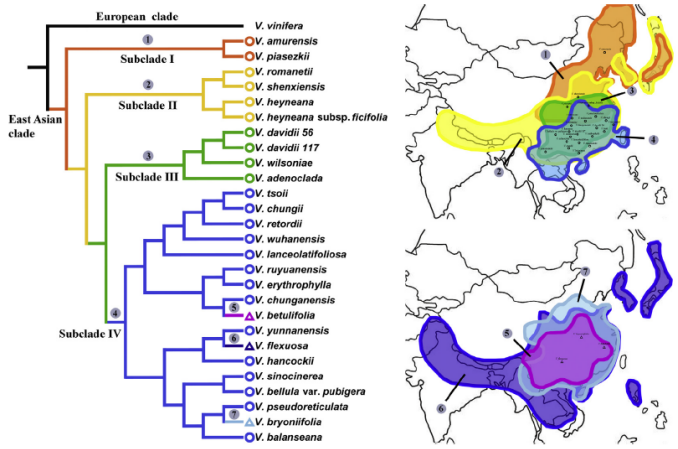
Process	Reservoir
Natural selection	Natural areas
Traditional breeding	Old vineyards, gardens
Modern breeding	Breeders plots, agricultural stations
Biotechnologies	Laboratories

➢ **Detecting** the potentially useful missing genotypes

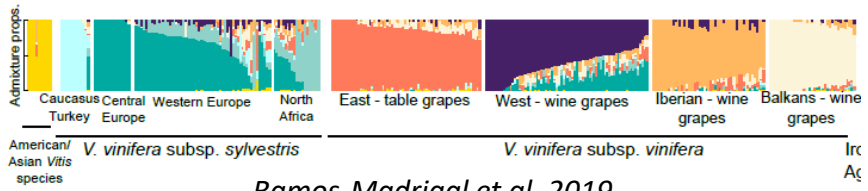
➢ **Protecting** the sources and the dynamic processes of diversity creation

Sources of grapevine diversity
Achievements

- Many advances in knowledge of grape diversity
  - ***Vitis sp.* taxonomy**: *Wen et al. 2018; Klein et al. 2018; Ma et al. 2020; Péros et al. 2020; Xu et al. 2020; Zecca et al. 2020; Fan et al. 2021; Li et al. 2021; Kenneth et al. 2022; etc.*
  - **Diversity structure**: *Migicovsky et al. 2017; Laucou et al. 2018; Liang et al. 2019; Ramos-Madrigal et al. 2019; Cunha et al. 2020; Magris et al. 2021; etc.*
  - **Variety parentage**: *Maras et al. 2020; Raimondi et al. 2020; D'Onofrio et al. 2021; Margaryan et al. 2021; Rockel et al. 2021; Torres et al. 2022; etc.*
  - **Clonal diversity**: *Gambino et al. 2017; Roach et al. 2020; Calderon et al. 2021; etc.*
  - **Mutant genotypes**: *Foria et al. 2020; Rockel et al. 2020; Tello et al. 2021; etc.*
  - **Phenotyping**: *Guo et la. 2019; Gutierrez et al. 2021; Flutre et al. 2022; etc.*
- Unexpected VGR of interest revealed
  - Mgaloblishvili; Orsolina; Coccalona nera; Riesling 49; Schwarze Zimmettraube; *V. californica*; *V. piasezkii*; *V. pseudoreticulata*; etc.
- Evidences that genetic erosion is still ongoing

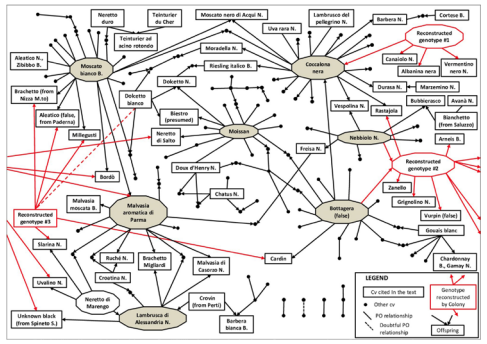


Ma et al. 2018



Ramos-Madrigal et al. 2019

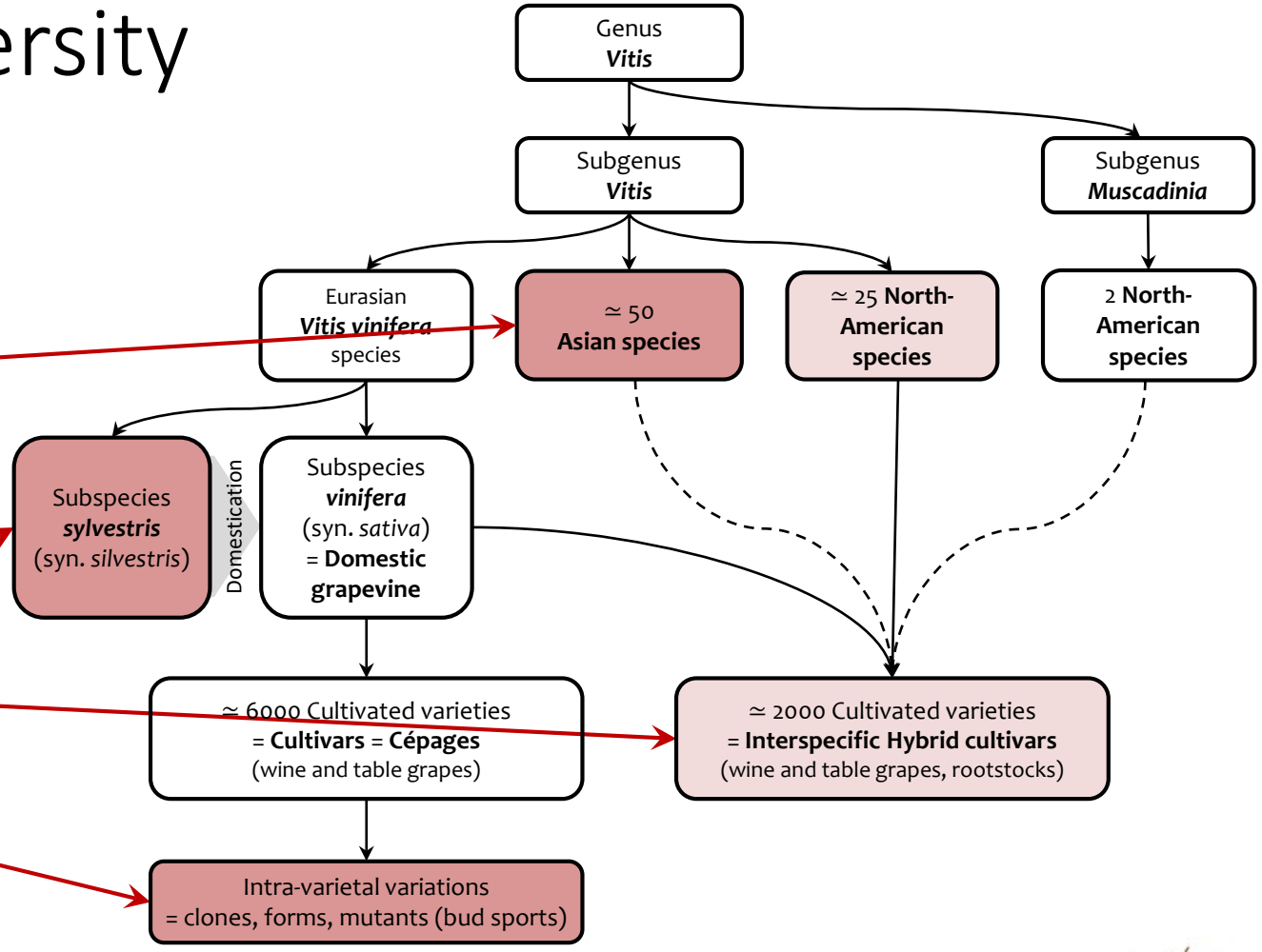
Calderon et al. 2021



Raimondi et al. 2020

Sources of grapevine diversity
Perspectives

- Deepen the scientific studies on
  - **Taxonomy** of *Vitis* species
    - Asia
    - Mexico and Central America
  - ***Sylvestris*** diversity: regional → global level
  - **Parentages**
    - Interspecific hybrids
    - Eastern *vinifera* varieties
  - **Clonal** identification and diversity
  - **Nucleotide** diversity of identified genes
  - Monitoring **indicators** for genetic erosion
- Promote any action to preserve reservoirs of diversity
  - **Wild compartment**, including areas not legally protected
  - **Cultivated compartment**: "old vines" initiatives
  - **Breeders and researchers**: encourage the safeguarding of new strategic VGR



CHENIN BLANC ASSOCIATION

CERTIFIED HERITAGE VINEYARDS

OIV

Censimento delle Vecchie Vigne

2 Collecting grapevine germplasm
Challenges

- Finding, sampling and grouping the **missing genotypes of interest**
  - Original surveys (vs. Exchanges between repositories)
- General method and requirements
  - Prioritise actions according to **urgency**
  - Preliminary **survey** work
  - Administrative **authorisations** and respect intellectual property rights
  - **Access** to source parcel. **Tagging**
  - On-site **identification** (ampelography)
  - Receive **local knowledge** (interviews)
  - On-site estimation of **sanitary** status (visual)
  - Harvest and **transport** (quarantine)
- Long and costly technical process

Table 2. Criteria to determine vulnerability of rare historical cultivars. Adapted from Maletić et al. (2015).

Category[1]	Status of cultivar	Number of individual vines	Estimated surface (assuming 5000 vines ha^{-1})[2,3]	Number of geographical sites	Status of propagation	Status of official registration in national catalogues[3]
CR (critically endangered)	Local neglected	<1000	<0.2 ha	≤2 wine-growing districts and/or ≤5 vineyards	Maintained in grapevine repository only/maintained in vineyard only/not or very rarely propagated/no interest for commercial cultivation	Generally no
EN (endangered)		1000-5000	<1 ha	≤2 wine-growing districts and/or ≤5 vineyards	Occasionally propagated	Generally no
VU (vulnerable)		5000-15,000	1-3 ha	≤2 wine-growing districts and/or ≤5 vineyards	Occasionally propagated	Generally yes
NT (nearly threatened)	Local	15,000-50,000	4-10 ha	Generally grown in 1 wine-growing district and/or ≤50 vineyards	Occasionally propagated	Yes
LC (least concern)	Minor	>50,000	>10 ha	Generally grown in >1 growing district	Regularly propagated	Yes, included in >1 wine PDO appellation
UC (no concern)	Widespread, international				Regularly propagated	Yes, included in >1 wine PDO appellations

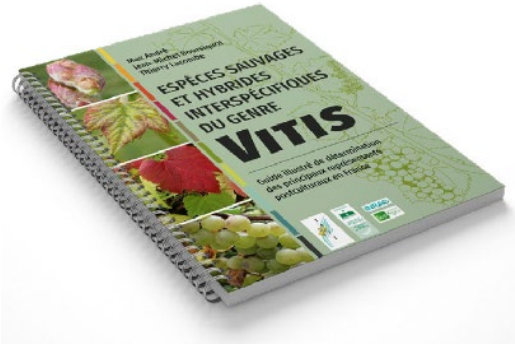
[1]Adapted for grapevine from the IUCN Red List, Categories and Criteria, version 3.1, 2nd edn (2012). CR, Extremely high risk of extinction; EN, very high risk of extinction; VU, high risk of extinction; NT, close to qualifying for or likely to qualify for a threatened category in the near future; LC, relatively widespread; UC, widespread and abundant.

[2]Adaptation to the conditions in every country is necessary. For example, a cultivar can be considered as "minor" if covering <0.02% of the total grape growing surface in a country, i.e., <100 ha on 500,000 ha or 20 ha in a total growing surface of 100,000 ha.

[3]Re-evaluation of the criteria should be carried out at appropriate intervals.

Maul et al. 2019 adapted from Maletic et al 2015

Collecting grapevine germplasm
Achievements

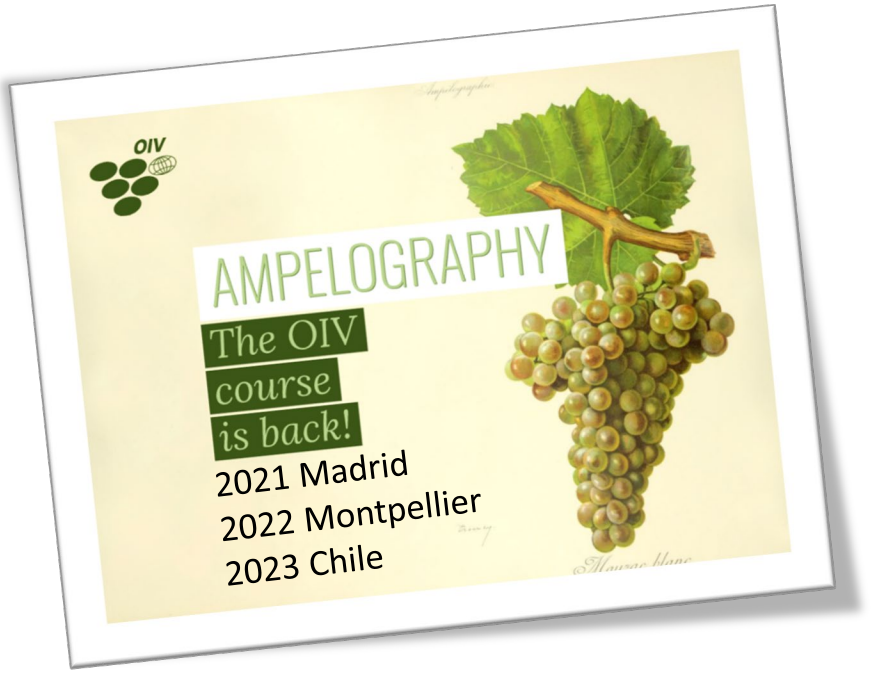


- Practical support tools
  - Recognition field **guides**: *Zdunic et al. 2017; André et al. 2021*
  - FAO MCPD **model** (passport data) → OIV descriptors
  - Integrated smartphone **apps** (GPS, photos, notes, audio, etc.)
- Recent examples of collecting campaigns
  - ***Vitis sp.***: *Heinitz et al. 2019; Huerta et al. 2021; Buck et al. 2022; Mata et al. 2022; etc.*
  - ***V. v. sylvestris***: *Naqinezhad et al. 2018 ; Luksis et al. 2021; Kupe et al. 2021; etc.*
  - **Traditional cultivars**: *Maras et al. 2020; Miazzi et al. 2020; Akram et al. 2021; Margaryan et al. 2021; Zombardo et al. 2021; Gago et al. 2022; Mendoza et al. 2022; Pszczólkowski et al. 2022; Torres et al. 2022; Yilmaz et al. 2022; etc.*
  - **Clones**: *Grigoriou et al. 2020; etc.* + Many private massal selections
- Types of VGR found
  - New species or subspecies: *Vitis shizishanensis (Ma et al. 2021)*
  - Presumed extinct varieties: Citronelle, Plant de Chaudefonds, etc.
  - Unknown varieties (no name, no local empirical knowledge), ex.:

Nb Total cv.	**Nb unknown cv.**	**Country** *(reference)*
33	**10**	Italy *(Miazzi et al. 2020)*
39	**15**	Italy *(Zombardo et al. 2021)*
45	**26**	Argentina *(Torres et al. 2020)*
18	**4**	Chile *(Pszczólkowski et al. 2022)*
15	**4**	Peru *(Mendoza et al. 2022)*
101	**51**	Montenegro *(Maras et al. 2022)*
221	**67**	Armenia *(Margaryan et al. 2021)*

Collecting grapevine germplasm
Perspectives

- Collecting grape wild relatives, traditional varieties and clones = **race against time**
  - Tomorrow it will be too late
  - Tomorrow, only exchanges between *ex situ* repositories
- Collecting **empirical local knowledge** is also urgent
  - Ethnobotanical works
- Recruit and train a **new generation of ampelographers**
  - Lack of skills in many countries; several retirements
  - OIV initiatives for new international ampelography courses →
- Future **field tools** for immediately…
  - … Identifying, by image capture? NIRS? DNA?
  - … Testing viruses?



- Difficulties in acquiring **new protected varieties**, **pre-breeding** and **research material**

3 Conservation of *Vitis* genetic resources

Objectives and options

- Goals
  - **Maintain** (living + regeneration) the grape material we decided to keep **long term**
  - Good **sanitary** status + good **quantity** + good **identity** + good **traceability**
  - Compliance with **national regulations** and **international agreements**
  - Best ratio **cost** / effectiveness / risk
- Types of preservation →
- Stakeholders
  - National / regional / local
  - Public / private collective / private individual
  - Inter-branch organisations / growers / amateurs
  - Collaborative networks

VGR Conservation	*In situ*	*Ex situ*
Wild grape relatives	Protection of natural areas	Collections: • **Vineyard-repository** • Insectproof greenhouse • *In vitro* culture • Cryopreservation • DNA bank
Cultivated grapevines	« On farm » preservation	

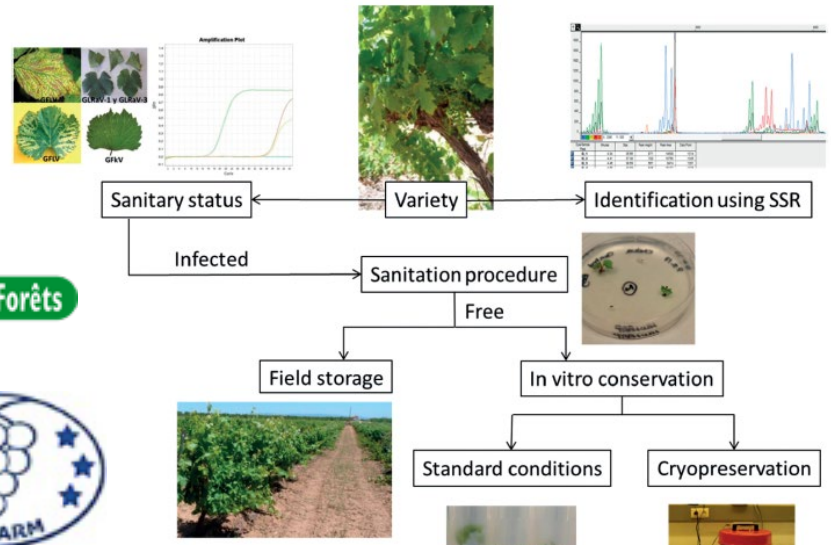
➢ Should everything be preserved?

➢ Can everything be preserved? Priorities?

Conservation of *Vitis* genetic resources

Achievements

- *In situ* initiatives
  - ***Vitis sp.*** in USA: *Pavek et al. 2003; Callen et al. 2016; Heinitz et al. 2019*
  - ***V. v. sylvestris*** in Europe: Germany, Switzerland, France, etc.
  - **Rare local varieties**: ECPGR "Grape on-farm" *(Maul et al. 2019)*
  - **"Old vineyards"** projects: Australia, California, Chile, France, Italy, South Africa, etc.
- *Ex situ* initiatives
  - Grape genebank **standards** *(Maghradze et al. 2015)*
  - **Sanitation** of accessions: USA, France, Spain
  - Great **databases** for sharing related information
  - Increase in **private** curators
  - Field collection **closures** or **endangered**
  - **Networks**, existing but not active enough
  - Insufficient conservation of **intra-varietal diversity** (clones)



Gisbert et al. 2017

Office National des Forêts

ON-FARM

Barossa Old Vines

vitis canarias
BASE DE DATOS DE VARIEDADES DE VID DE CANARIAS

WELCOME TO ARMENIAN VITIS DATABASE

Published: 05 February 2014
Grapevine gene bank under threat
Declan Butler
Nature **506**, 18 (2014) | Cite this article
82 Accesses | **1** Citations | **73** Altmetric | Metrics

eurisco
Finding seeds for the future

The European *Vitis* Database

French Network of Grapevine Repositories
Database of the collections
Home Search My selection

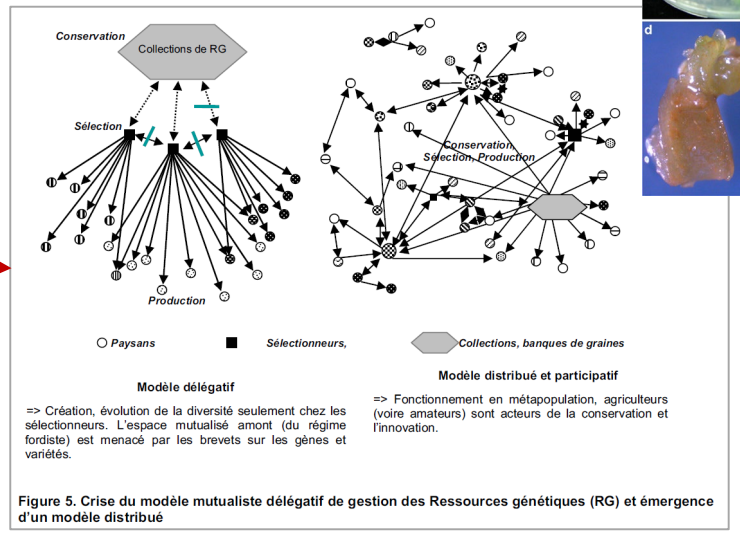
Conservation of *Vitis* genetic resources

Perspectives

- Insect-proof **greenhouses**
  - Against virus infections (GPGV, GRBV)
  - Ongoing projects in France, USA
  - Cost: investment and operating?
- **Cryopreservation**
  - Ongoing works: Brasil, Croatia, Egypt, France, New Zealand, USA
  - Conservation? and/or sanitation?
- Common **DNA bank** to be created?
- **Networks** to be strengthened and animated

➢ **Funding** must be sufficient and constant

Markovic et al. 2015; Pathirana et al. 2015; Bi et al. 2017; Haggag et al. 2018; Bettoni et al. 2021



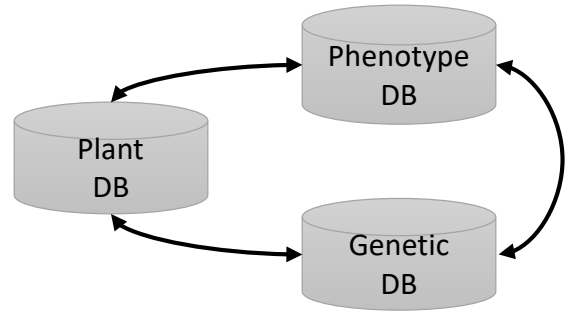
Bonneuil 2006

4 Characterization of grape genetic resources

In brief → see session 2 "Phenotyping"

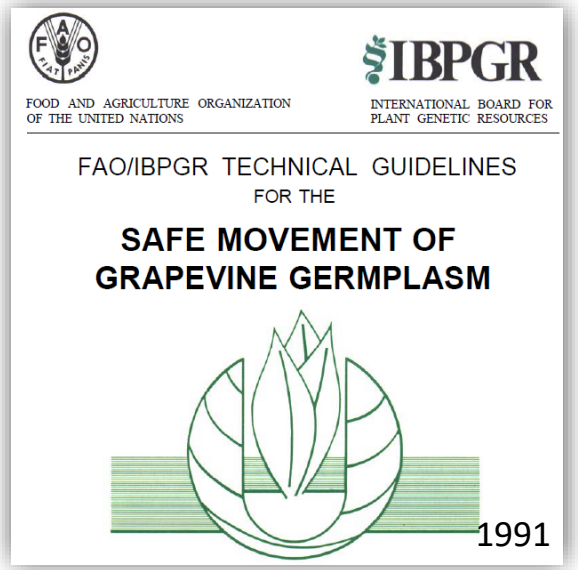
Scientific and technical information:
- Identity, taxonomy, pedigree
- Morphology, anatomy, physiology
- Sanitary status
- Agronomic traits
- Technologic (wine/table) traits
- Genetic data
- Bibliography →

- Challenges
  - **Required** for VGR genetics, breeding and direct use
  - Gather **all information** potentially useful for using VGR
  - **FAIR** data: Findable, Accessible, Interoperable, Reusable
- Achievements
  - New **tools** (sensors, dataflows, softwares) applied at medium/**high throughput**
  - **Many** evaluation works and **publications** (articles, books, websites), for many **traits**!
- Perspectives
  - Finalize **harmonization of ontologies** and formats: Integrape, OIV, etc.
  - Many **unpublished data** are sleeping in labs → storage in available databases or data-papers
  - **Cross-links** with germplasm collection and genetic databases



5 Distribution of *Vitis* genetic resources

Framework



- **Quantity** and type of material (time, cost)
  - Scientific: explant, cells, DNA, etc.
  - For crossbreeding: seeds and pollen
  - For multiplication (buds): cuttings, grafted plants
- **Quality** = sanitary status (time, cost)
  - National and European regulations
    - Project of OIV resolution
  - Quarantine
- **Legal status** (time)
  - Commercial *vs.* research material
  - Intellectual Property (IP): plant patents, trademarks
  - CBD Rio 1992
  - Nagoya Protocol on "*Access and Benefit Sharing*" (ABS) 2010

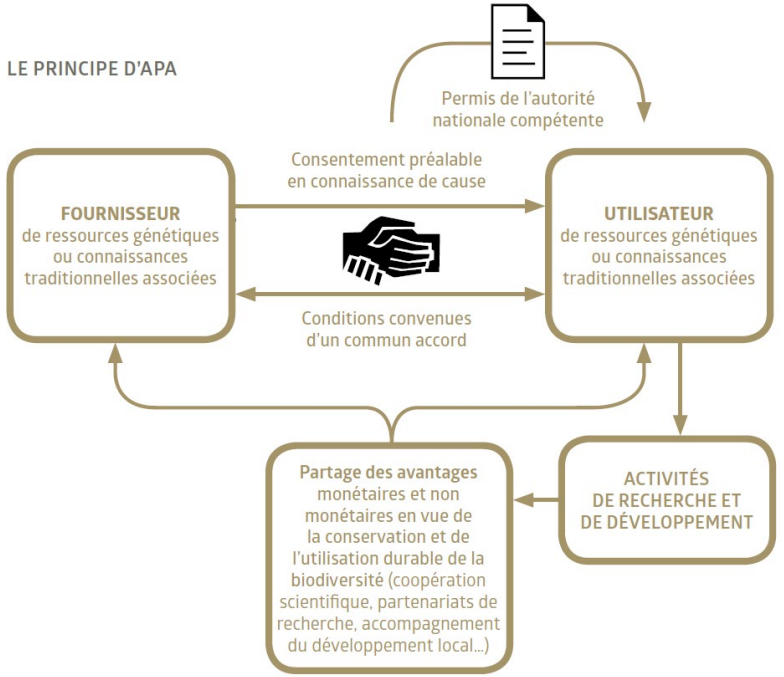
- Authorizations for circulation
  - Phytosanitary passport
  - Material Transfer Ageement (MTA)
  - Traceability (PUID)

Convention on Biological Diversity

COP10/MOP5
AICHI-NAGOYA
JAPAN 2010

Distribution of *Vitis* genetic resources

Current situation



- All regulations are **justified**
  - Sanitary risks
  - Intellectual Property, ex. “Access and Benefit Sharing” →
- But significant **increase in paperwork** for each VGR exchange
  - Evolution of curator skills and workload
  - Many researchers and breeders are not aware of these regulations: need for information and training
  - Unintentional or intentional circumvention of the rules
  - Risk of blocking or reducing the VGR exchanges
- However, **effective circulation** of VGR is necessary for them to provide the expected uses

6 Uses of *Vitis* genetic resources

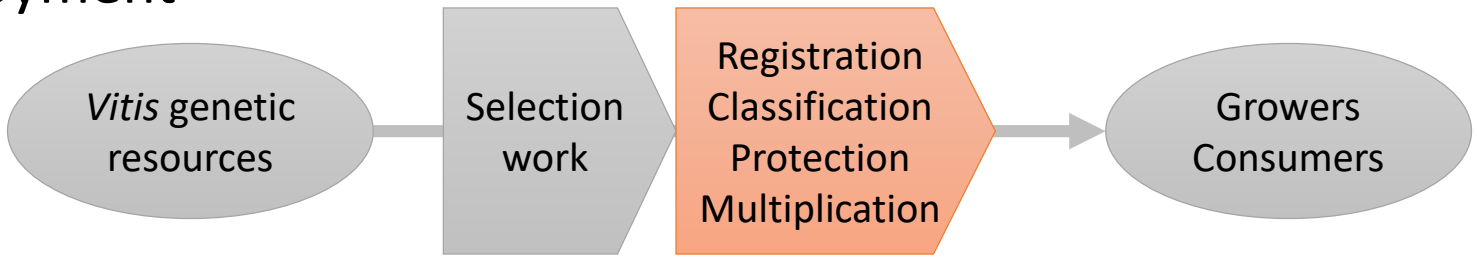
Many expectations

- Several **goals** (cf. introduction)
- Different **strategies**
  - Re-cultivation of local traditional varieties
  - Acclimatization of foreign varieties
  - Bud sport selection
  - Clonal selection
  - Crossbreeding of chosen genitors
  - Biotechnologies
- Multiple **user profiles** (pros and cons)
- One **legal framework** for deployment
  - Prior experimentation
  - Definitive cultivation


Rossula bianca


Agiorgitiko


Voltis

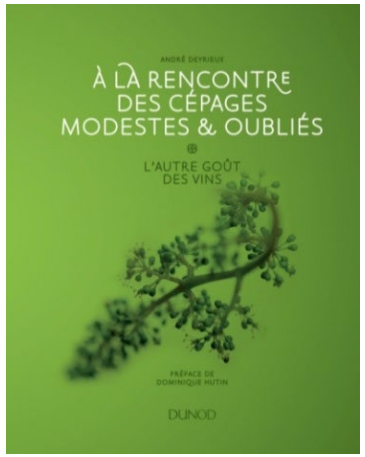


CPVO Community Plant Variety Office | UPOV | GEVES Expertise & Performance | C.T.P.S. Comité Technique Permanent de la Sélection des Plantes Cultivées | FranceAgriMer

Uses of *Vitis* genetic resources

Current paradoxes

- **Paradox 1**: interest for **minor varieties** *vs.* cultivation of **international varieties**

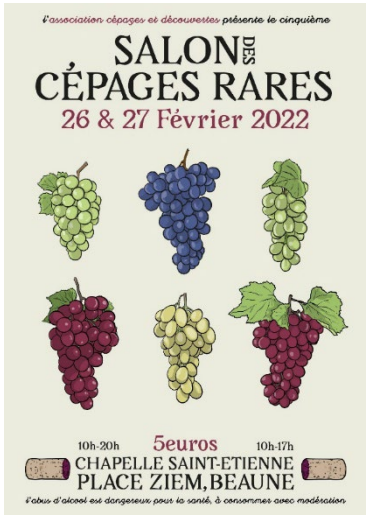


Grape Adventure: Unusual Wine Grape Varieties Around The World

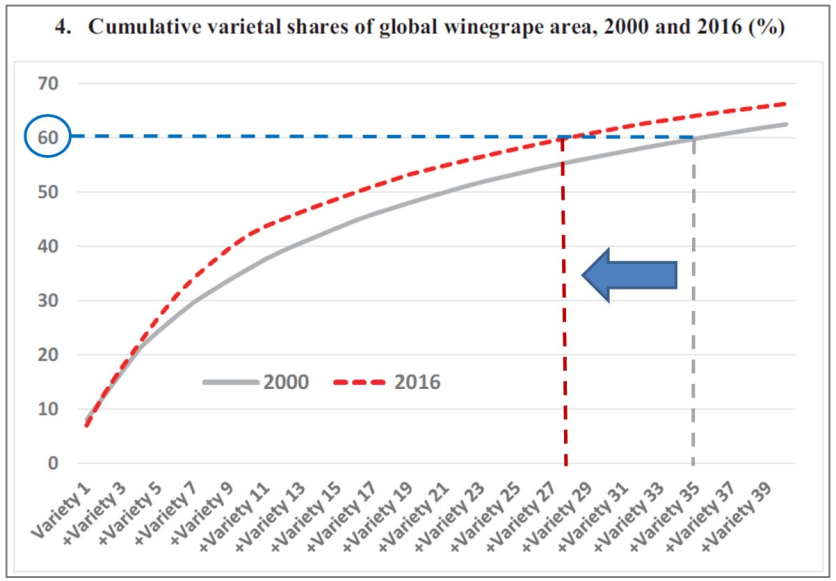
Indigenous Grapes, Forgotten Grapes?

The rare-grape collector

Rediscovering the forgotten grapes!



But…



Anderson and Nelgen 2020, modified

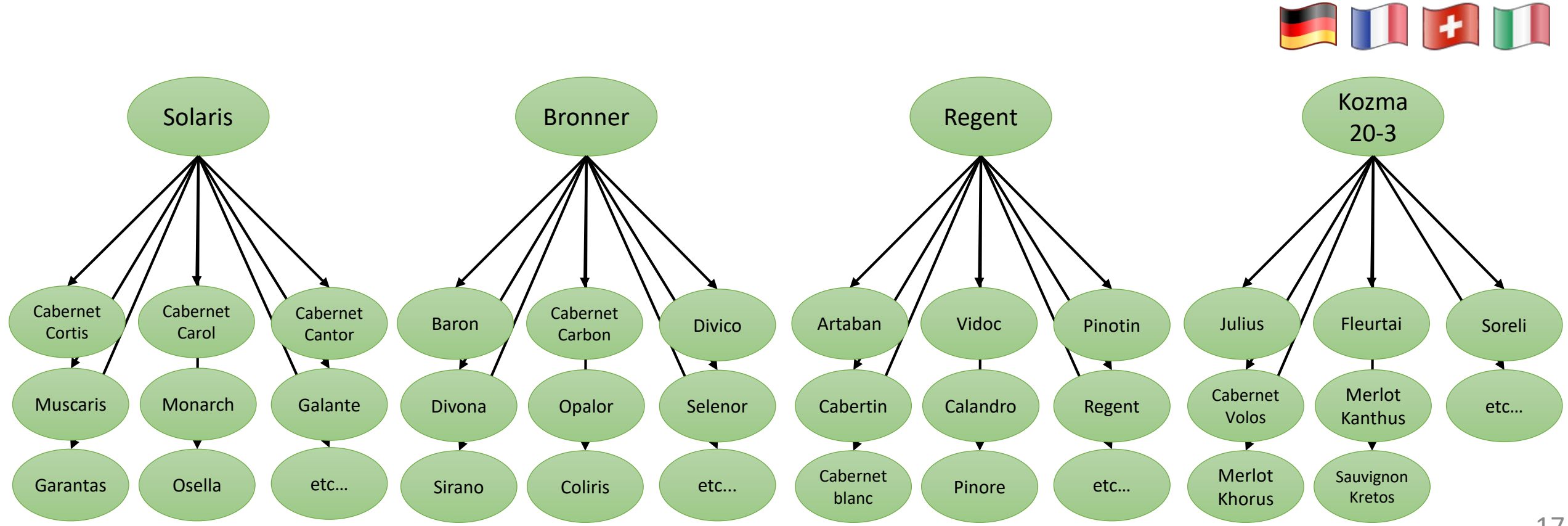
Traditional varieties registered in 2012-2021	Number	Total surface
France	39 var.	23 ha
Italy	80 var.	Few

Sources: //plantgrape.plantnet-project.org; //catalogoviti.politicheagricole.it

Uses of *Vitis* genetic resources

Current paradoxes

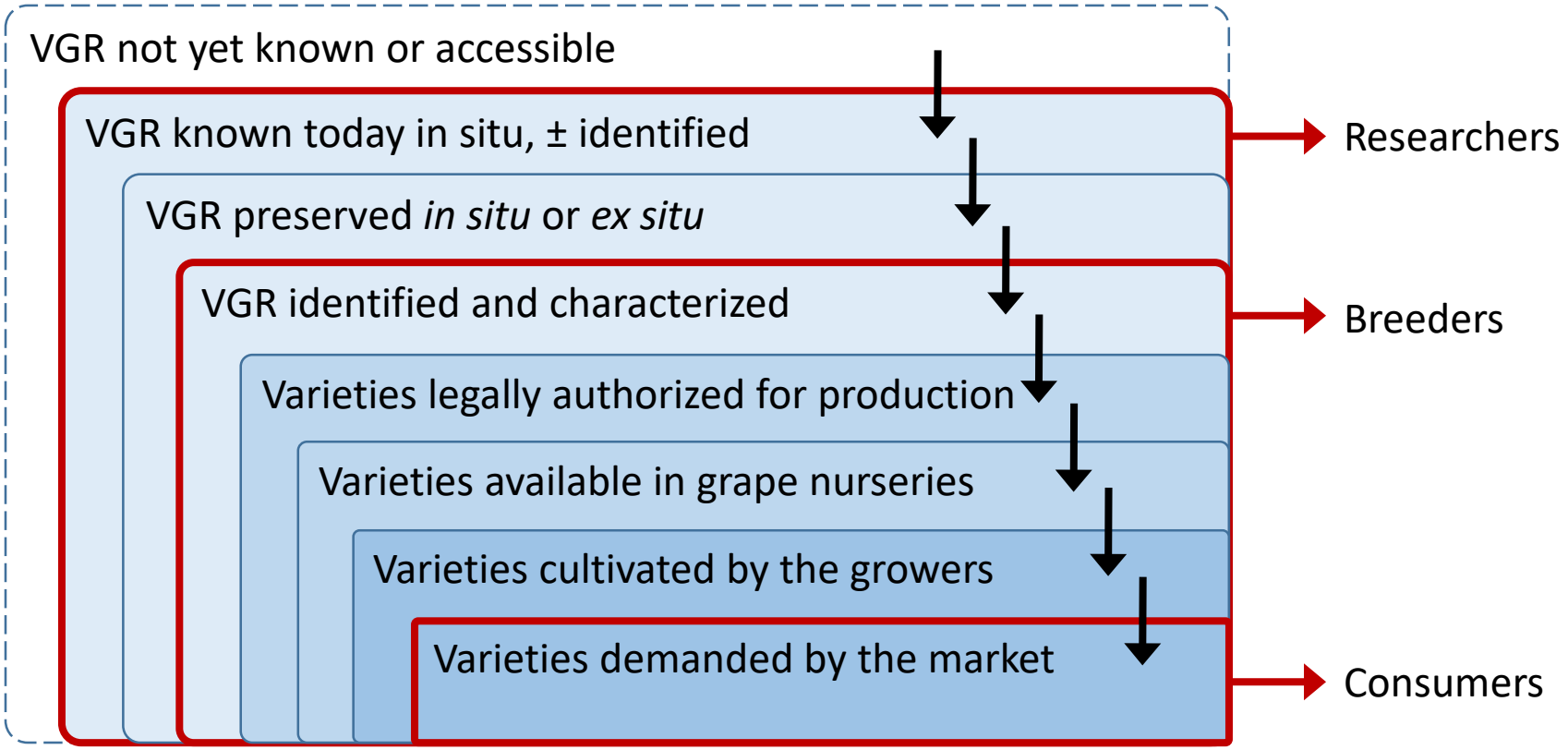
- **Paradox 1**: interest for minor varieties *vs.* cultivation of international varieties
- **Paradox 2**: number of **potential genitors** *vs.* **narrow genetic basis** of new bred varieties



Uses of *Vitis* genetic resources

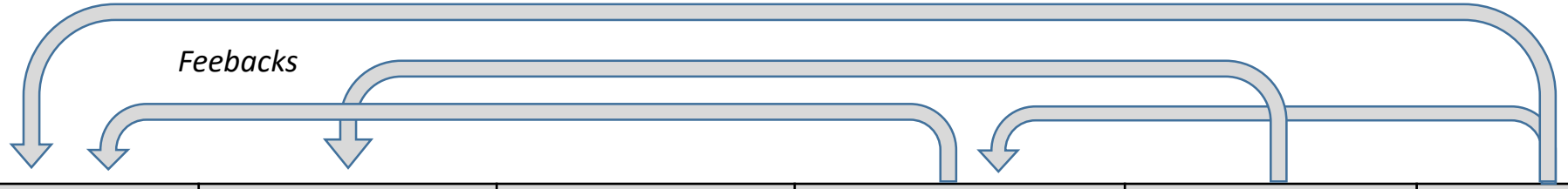
Continuous work still to be done

- **Good period for grapevine diversification**
  - Traditional varieties
  - New varieties
  - Rootstocks
- **Discrepancy** between material available and material actually used
  - Researchers, breeders, nurseries, growers, etc.
- Continue to **reduce these gaps** by studying and managing the VGR



Conclusion

Subjective summary



***Vitis* Genetic Resources**	**Sources of diversity**	**Collecting**	**Conservation**	**Characterization**	**Distribution**	**Uses**
Challenges	± Stable for technical, scientific, socioeconomical, legal and political aspects *(except increasing paperwork…)*					
Achievements	Revealed	Stable		Significant increase	Stable	Increase
Perspectives	Threatened	Priority	Caution	Very favorable	Caution	Favorable

Conclusion

Take-home messages

1. **No** grape genetics, breeding, selection **without** *Vitis* genetic resources
   - Priorities should be addressed collectively
2. **VGR = Multiplicity** taxonomic levels, varieties, goals, priorities, heritage, traits, stakeholders, strategies, regulations, empirical knowledge, agreements, geographies, threats, publications, expectations, pools, applicants, genes, data, etc. → permanent and difficult **integration**
3. **Do not re-invent** existing tools, infrastructures, bodies, methods, etc. but promote their implementation, modernisation and **coordination**
4. Recurring issue of **funding** which must be sufficient and **stable**
   - In **competition** with other grapevine research expenses (genomics, phenomics, metabolomics, etc.) to arbitrate
   - Need for **new positions** for young colleagues in this **strategic and exciting area of research and action**

Thank you for your attention

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