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History of breeding programmes for fungus resistant grape varieties in Europe, France and the Occitanie region

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Fungus tolerant grape varieties (RVs) are emerging as a promising solution in a viticultural context characterised by growing societal, environmental, and regulatory tensions. Since the 1930s, several countries have launched research programmes that aim at developing disease-resistant hybrids. Today, 66 resistant grape varieties are registered in at least one of the European catalogues. The historical overview and dynamic integration of RV have not been the subject of a large number of scientific articles. This makes it necessary to explore grey literature such as Vitisphère (www.vitisphere.com), a French daily online magazine created in 2000 specialised in wine industry. Through a press review, this article provides historical background to European breeding programmes and an overview of their perception in France and Occitanie, gathering over 543 articles on the topic of RVs published between 2009 and end June 2024.

Drivers of varietal innovation

After the French sanitary crises in the 19th century due to the introduction of powdery mildew, phylloxera, downy mildew and black rot, the use of hybridisations and fungicides became possible control strategies. The hybrids had a certain amount of success, notably between the two world wars when mineral resources to protect traditional sensitive grape varieties were limited. In the 1960s, the use of hybrids gradually gave way to synthetic fungicides, which became the main control strategy[1], thanks to the development of the chemical industry and the exclusion of the hybrids from the French Protected Designation of Origin regulation (PDO)[2].

Nowadays in Europe, 70% of fungicides are used to protect grapevine, which represents over 5% of utilised agricultural area, making this crop one of the largest consumers[3]. Also called Resistant Varieties (RVs) obtained through interspecific crossings between *Vitis vinifera* and American or Asian species require few fungicide applications, considerably reducing product use, production costs and carbon footprint[4]. Results of interspecific hybridisation, and successive backcrosses show that a large proportion of the genome (>95%) of modern RVs originates from *Vitis vinifera*, combining berry quality and disease tolerance. Over the past twenty years, sustainability has become an important issue in the wine industry. The increasing grower and consumer awareness regarding this issue has spurred the industry to innovate, leading to an acceleration in breeding programmes[5].

In Europe, four countries lead the research on RVs, with two strategies that stand out for their regulatory and cultural context, the type of players involved, and the positioning of public institutions:

1. **Germany, Italy, Switzerland**: proactive approach, with dynamic national programmes, private and public sector involvement.
2. **France**: cautious approach to preserving resistance genes, with a recent proliferation of regional programmes involving the industry.

From contrasting beginnings to current dynamics in France and in Europe

A rupture between France and European countries occurred in the 1950s. The emergence of a restrictive post-war regulatory framework, following the failure of "Direct Producer Hybrids" (50% *Vitis vinifera* genome, generally associated with low quality wine)[1], considerably slowed down varietal innovation in France.

In 1956, the French Research Institute for Agriculture, Food and the Environment (INRAE) launched an intraspecific hybridisation programme involving two *Vitis vinifera*, limiting genetic diversity and depriving itself of resistance genes. Conversely, as early as the 1930s, Germany, Hungary and Switzerland opted for interspecific hybridisation[1] (Figure 1).

In 1974, Alain Bouquet, researcher at INRAE Montpellier, launched an interspecific hybridisation programme, backcrossing *Muscadinia rotundifolia* with various *Vitis vinifera* Mediterranean grape varieties (Figure 1). These varieties named "Bouquet" have one locus of resistance against powdery and downy mildew. In 2000, the Alsace INRAE center launched the national programme, using pyramiding to combine several resistance genes and produce polygenic varieties, and thus reducing the risk of disease bypass [6].

Since 2006, Italy has been developing its own breeding programme. Improved genetic techniques, and the partnership between public research and the VCR nursery, are conducive to accelerating the dissemination of these new varieties.

Until 2012, grapevine breeding was conducted in France by public research bodies. Responsibility has since shifted to the French Wine and Vine Institute, with emerging regional collaborations involving research, breeders, and industry organisations aiming to develop RVs tailored to French terroirs through strategic crossings. Currently, 10 programmes are under way in various French wine growing regions (Figure 1).

France's lag in varietal innovation is attributed to regulatory hurdles, delayed

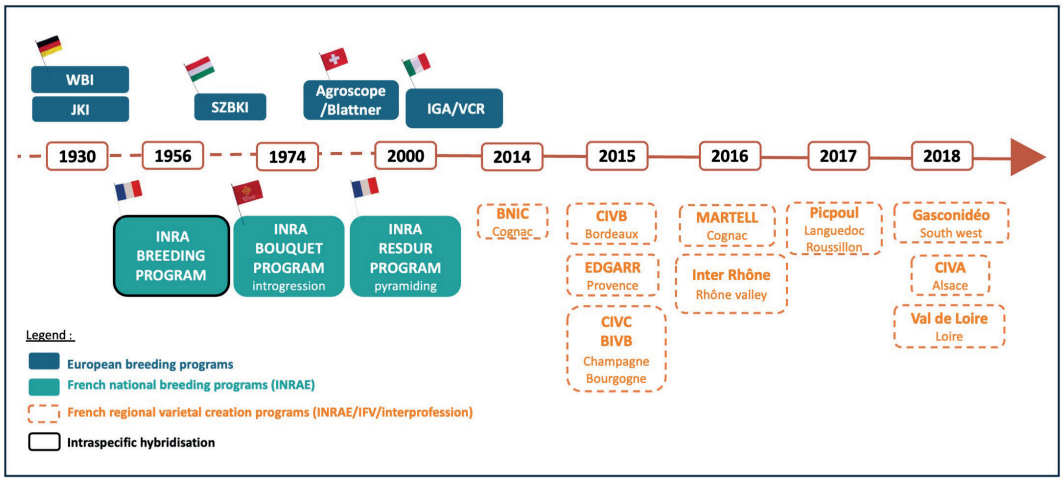

FIGURE 1. An overview of the history of grapevine breeding programmes in Europe and France.

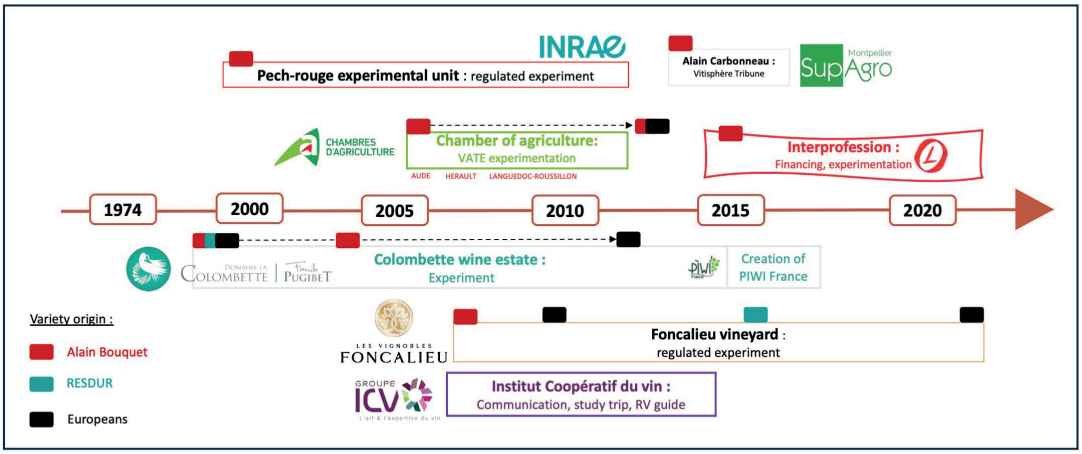

FIGURE 2. An overview of the key players who acted in favour of the resistant varieties in Occitanie.

industry involvement, and emphasis on resistance gene pyramiding by INRAE. This poses challenges for winegrowers eager to experiment, particularly in the Occitanie region (South of France), where early interest in Bouquet varieties was sparked by foreign competition.

The appeal for Bouquet varieties in Occitanie region

The Occitanie region stands out for its "wine mosaic" spread across 270 000 ha, representing 5% of the word wine growing area[7]. Figure 2 provides an overview of the dynamics of the RV key players, sourced from the French technical press review Vitisphère.

Domaine La Colombette was one of the first French wine estates to experiment with available foreign and Bouquet's varieties, before starting to create their own. They brought varieties to registration and founded the PIWI France association in 2016, a spin-off of the international association[8], to collectively defend RVs. Their involvement has played an important role in the evolution of French legislation.

Since 2008 in the Occitanie region, two Chambers of Agriculture (*Chambres d'Agriculture* - local public development organisations) have been conducting regulated trials on Bouquet's varieties with a view to including them in the French catalogue. They retargeted their experimentation towards ResDur and foreign varieties in 2010, following public directives. However, some organisations sent a letter to the French administration expressing the profession's interest in Bouquet Varieties and the need for a rapid experimental mechanism.

Since the 2000s, INRAE Pech-Rouge, an experimental centre in the Aude region, has integrated Bouquet varieties into various research programmes, resulting in promising wine quality. Indeed, Alain Bouquet's breeding effort, with a focus on Mediterranean grapes, is well-suited to local typicity.

Other players in Occitanie vineyards have chosen to experiment on available varieties listed in the European catalogue, such as ResDur or German varieties with a strong growth in recent years[9]. Others have organised several study trips to Germany and published a "Guide book to RVs", with technical data sheets providing further information on these varieties.

The Occitanie wine industry in the eastern part of the region favours Bouquet's variety - despite its single locus of resistance against powdery mildew - due to its wine quality and agronomic traits. Seeking a regulatory framework for experimentation, the main grower association, Comité Interprofessionnel des Vins du Languedoc, issued a call for winegrowers' interest in 2016 in Vitisphère. This led to the national Oscar observatory programme collecting and sharing information about RVs[10], and to the introduction of temporary classification. Finally, in February 2023, INRAE signed a letter of intent to deploy nine Bouquet varieties in the eastern part of the Occitanie region by 2025.

Towards a more favourable regulated environment

In Europe, the cultivation of GMOs (genetic modified organisms) is prohibited and strictly regulated. Since 2001, New Breeding Techniques (NBT), like CRISPR-Cas9, promise agriculture with reduced dependency on pesticides. In early 2024, the EU Parliament proposed to regulate plants obtained by NBTs differently, distinguishing those that could result from natural mutations previously subject to the same regulations as GMOs, such as RVs. Negotiations are underway to finalise the law, which could accelerate the deployment of RVs. VCR, an Italian company, which has already been running a research programme on RVs, is awaiting this approval to start their trials.

In December 2021, new European regulations lifted the 1970 restriction, allowing hybrids to be included in the specifications of appellations. French PDO vineyards, such as Bordeaux and Champagne, consider it an opportunity to reduce inputs and adapt to the "No Treatment Zone", a regulation to protect sensitive environments - a major step forward, given that wine consumption is dominated by appellation wines.

Conclusion

A look at the history of varietal innovation in French vineyards reveals a complex path marked by strategic choices and regulatory changes, with regional disparities. In eastern Occitanie, by recognising the advantages of Bouquet's varieties, the influence of bold players has been decisive, leading to innovative and sustainable viticulture. Meanwhile, interest in other cultivars, particularly white ones, is growing across the region. It should be noted that this short press review does not fully reflect the complexity of the topic.

With obvious dynamics, evolving regulation and regional initiatives in varietal development since 2010, technical and regulatory issues have virtually been resolved. The challenges ahead lie in dissemination to growers and consumer acceptance. We should keep in mind the potential of RVs as a solution to climate change and as a model for sustainable and resilient viticulture. To reach this goal, the RESSENTI project, initiated in 2023, focuses on grower adoption and consumer acceptance of RV wines, as well as effective marketing strategies to support the deployment of this innovation. ■

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Additional data: *A table in French about this literature review is available upon request to the corresponding author.*

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