sustainability

MDPI

Article

A Comprehensive Economic Examination and Prospects on Innovation in New Grapevine Varieties Dealing with Global Warming and Fungal Diseases

Etienne Montaigne [1], Alfredo Coelho [2,*] and Samson Zadmehran [3]

[1] Département Sciences Economiques Sociales et de Gestion, L'institut Agro, SupAgro Montpellier, 34060 Montpellier, France; etienne.montaigne@supagro.fr
[2] Department Enterprises and Territories, Bordeaux Sciences Agro, 33170 Gradignan, France
[3] Faculty of Social Sciences, Organisations and Institutions (UFR 4), Université Paul-Valéry Montpellier 3, 34199 Montpellier, France; samson.zadmehran@univ-montp3.fr
* Correspondence: alfredo.coelho@agro-bordeaux.fr

Abstract: The present study focuses on the assessment of the development perspectives of the new grape varieties that are resistant to fungal diseases and thus promote the reduction or the suppression of phytosanitary treatments. The study also discusses new grape varieties dealing with global warming. Our methods rely on direct surveys with researchers and stakeholders completed with a synthesis of the scientific literature and edited research programs. This approach proposes an explanatory and a comprehensive investigation. It includes an overview of the current state of the art of the supply of technology, the presentation of the strategies of the main actors and stakeholders involved in the innovation chain, a synthesis of the current scientific and technical controversies, and an analysis of the influence of the institutions and legislation. Furthermore, we provide an evaluation of the previous research program on new grape varieties of the French National Institute for Research in Agronomy (INRA) and of the outcome of the diffusion of new grape varieties implemented in the south of France. This analysis will allow us to discuss the conditions for the success of this innovation as a competitiveness factor.

Keywords: innovation; resistant grapevines; wine chain; France

Citation: Montaigne, E.; Coelho, A.; Zadmehran, S. A Comprehensive Economic Examination and Prospects on Innovation in New Grapevine Varieties Dealing with Global Warming and Fungal Diseases. *Sustainability* **2021**, *13*, 13254. https://doi.org/10.3390/su132313254

Academic Editors: Veronica Sanda Chedea and Maria Lucia Iliescu

Received: 21 June 2021
Accepted: 20 August 2021
Published: 30 November 2021

1. Introduction

Innovation in grape varietals played an essential role in the history of viticulture. The solutions provided by the new hybrid vines, direct producers, and rootstocks to the Phylloxera crisis in the 19th century are a good example. Since World War II, varietal creation was only considered in public research. Some specialists, at least in France, considered that all important grape varietals were already known, and therefore, the development of new grape varieties was not an essential area of investigation. The findings of the research programs started in 1956 led to some marginal outcomes, but their development history can shed light on the assessment of the new research programs.

Obtaining a new grape variety is a long-term process that can last up to 20 or 30 years. According to the evolutionary approach [1], it is the technological paradigm of the research programs intending to improve the proprieties of the plant that defines the technological trajectory. In relation with this delay for the obtaining of new grape varieties, the success of the diffusion of the new varieties faces three main difficulties: (1) Professionals need to agree on the relevance of the paradigm, i.e., on the characteristics of the research program; (2) A gap appears between the characteristics of new varieties proposed for dissemination and the new perception of the needs of those professionals or their market, which are broadly different 25 years later, and (3) The rhythm of the diffusion of these innovations, approximately 2.5%/year, is related to the life-cycle of the vine plant.

In France, the awareness of obtaining grape varieties resistant to fungal diseases emerged quite late, except in the case of the work of one research director from the INRA. His investigation started the improvement of such varieties in the 1980s. His work was only recently resumed. Since World War II, the research in Europe on the new grape varieties has mainly been at the initiative of researchers working for public institutions. However, the contractual relationships with firms in charge of disseminating those varieties—the nurseries—vary considerably according to the countries, the size, and the strategy of the grape nurseries. The issues related to licenses and royalties are an essential matter.

Therefore, the industry is characterized by the presence of various resistant grape varieties created in several European countries by researchers or grape nurseries (see, for example, [2]). In each country where the new varieties were created, new varieties were registered in each national catalog, but the registration of those foreign varieties were not, until today, extended to the French national catalog. Therefore, and contrary to the already existing grape varieties listed in the national catalogs, it excludes those varieties from applications for potential subsidies (conversion of vineyards…) from the Common Agricultural Policy (CAP). Some innovative grape growers anticipated the social demand and adopted those resistant varieties without any public subsidies. In addition, those grape growers processed the grapes and established a label to highlight this environmental advantage.

A scientific controversy adds to the environmental and social issues. It deals with the 'stability of the resistance' over time. In short, the first varieties obtained featured a 'monogenic' resistance, which is considered by some researchers as easily circumvented. Such researchers block or try to slow down the (market) availability of new resistant varieties. They choose to wait for the registration at the French national catalog of a 'new wave' of grape varieties whose resistance to fungal diseases would be 'polygenic'. This scientific controversy creates uncertainty for public officers and a standby position criticized by those wishing for a faster diffusion of those innovations in the wine chain.

The selection of varieties adapted to the global warming is more recent and comes in addition to the resistant properties. At first glance, several current alternatives seem to postpone the urgency of the new creations.

Furthermore, the wine production in Europe is traditionally characterized by quality designations of origin—PGI and PDO—which base their reputation on the main traditional grape varieties and therefore exclude new grape varieties. In France, those geographic indications account for approximately 95% of the wine production and create most of the value in the wine chain [3,4]. This exclusion inhibits significant extension.

Finally, the issues allowing the rapid diffusion of resistant grape varieties excluding pesticides might include the following: fostering the rate of renewing vineyards, registering new European grape varieties in the French national catalog, the full or partial acceptance of the new grape varieties in PDO areas, the increase of the political pressure from ecologists and the civil society about the reduction of phytosanitary inputs, the integration of those varieties in the national endowment of the Common Market Organization (CMO) for wine for the restructuring of vineyards or, finally, the insertion of resistance genes in traditional varieties through faster means than classic genetics. However, the strategy consisting of the creation of new varieties through GMO methods seems not adapted to the society, including at the research level.

The main novelty of the last 15 years is based on the fact that innovation in grape varieties was mainly 'demand driven'. Very few attempts were 'supply driven'. The two main factors influencing research were the pressure from the society rejecting all the phytosanitary products (I) and the fear of grape growers concerned with the consequences of global warming (II). The choice of the technological paradigms was not the same in France and in other parts of Europe, particularly in Germany, Switzerland, and Italy. Therefore, the assessment of such major technological innovation is based on the comprehension of past technological trajectories, the current state of the art of the supply of technology, the strategies of the stakeholders, including the leading institutions of the wine industry,

the characteristics of the market, and the establishment of foundations for the qualitative definition of the resistant grape varieties.

2. The Evolutionary Framework and the Innovation Chain

Contemporary studies in economics and in strategic management focusing on evolutionary theories are organized around three main research streams [5]: the ecology of populations (I); the dynamics of resource-based view (RBV) (II); and the economics of innovation (III). A first stream of research focus is on the 'ecology of the populations' [6], which postulates that the long-term change (behavior, survival rates) in the diversity (number and distribution) of organizational forms in an industry occurs through selection rather adaptation. The process of natural selection is dynamic and acts as an optimization process.

In the light of this theory, the relationship organization of the environment occurs mainly through selection. Accordingly, changes in resources, legislation, or technologies transform the competitive environment, and firms must anticipate those changes in order to survive in an industry. The foundations of this view were criticized by Christensen [7] as being a normative theory in response to competitiveness challenges.

The second research stream focuses on the dynamic capabilities [8–10]. It postulates that a firm's competitive advantage relies on the capacity to renew competences and to achieve a fit in a changing competitive environment [10]. Accordingly, firms must follow a certain trajectory or path to competence development. The development of some unique competences (R&D, ability to innovate in products or processes…), either individually or collectively developed and difficult to replicate or to imitate, creates a 'superior' advantage in the market [9]. Firms must take advantage of technological assets underestimated by the competitors and be able to access information and integrate internal and external knowledge related to such innovations [8,11].

The third research stream, retained in our explanatory investigation, follows the evolutionary framework of technical change [12–16]. Evolutionary models try to explain the evolutions across time and, more broadly, the way the agent or the process under observation was reached. The explanation includes random elements that renew or generate the variables under study, to which we add sorting and selection mechanisms. Generally speaking, in the society, on one side, such models include imperfect learning and discovery mechanisms operating through trial and error. On the other side, such models include selection mechanisms. These models specify the determinants of adaptation (fit), which supposes both the determination of the selection unit and the main mechanisms for which the selection takes place.

The analogy with evolutionary biology uses three principles: (1) the principle of heredity is based on a fundamental unit of selection: the gene, which represents permanence but also the element on which mutations and selection will bear. As a comparison, the gene in economics is represented by the organizational routines of a firm: identical reproduction routines or routines of change through innovation; (2) the principle of selection links the level of the genotype and the individuals (the phenotype), at the basis of selection by the environment, and it is characterized by interaction processes making selection dynamic. In the field of economics, selection is represented by competitive pressure on the market; (3) the principle of variety includes mechanisms generating variations in the genotypes of the population (mutations) and therefore in the phenotypes (the shape of individuals) of this population. By analogy, change in economics is innovation.

In this approach, we take the two fundamental concepts of Giovani Dosi: the technological paradigm and the technological trajectory. The technological paradigm represents what we are looking for, how and why, and also by whom this research is done.

> '*In broad analogy with the Kuhnian definition of a 'scientific paradigm', we shall define a 'technological paradigm' as 'model' and a 'pattern' of solution of selected technological problems, based on selected principles derived from natural sciences and on selected material technologies.*'. [14], p. 152

The technological trajectory provides the economic dimension of the technological paradigm by combining the research program and its economic evaluation by the various stakeholders: firms, sectors or industry, market, development agencies, or those in charge of economic policies.

'We will define a technological trajectory as the pattern of 'normal' problem solving activity (i.e., of 'progress') on the ground of a technological paradigm' [13]. Therefore, the technological trajectory represents the improvement path taken by a given technology. Such trajectory takes into consideration the opportunities perceived by the technologists, the market conditions, and the influence of other economic evaluation mechanisms which combined determine the profitability of such improvements. It can also be represented by the overall benefits associated with the technological variables considered as relevant for the program.

Therefore, the interest in adopting Dosi's concepts is to invite the researcher studying a group of firms and a particular technology to seek the existence—and to characterize the nature—of this orientation. In this line of thought, the role of stakeholders, firms, or institutions emerge spontaneously [16].

A complementary perspective of the innovation sector was considered in a systemic and finalized approach which makes it possible to identify the stakeholders participating in a sectoral technological trajectory [16]. In line with the above considerations, we define an innovation chain as a set of firms and of private or public organizations participating in the process of developing a technology; i.e., in the solution of a paradigm. Such participation involves its economic and technical evaluation in the firms concerned and therefore the definition of a technological trajectory aggregating those of elementary firms. Considering the definition of a wine chain as a finalized and oriented system, we can arbitrarily 'isolate' two systems and its most significant relations of domination, regulation, or dependence.

Figure 1 illustrates the approach in viticulture and oenology. It represents two innovation chains: plant material, from one side, and membrane separation techniques, from another side. Both make significant contributions to the evolution of the technical and economic conditions of the wine chain.

Following this evolutionary framework, Ulrich Witt [17] provided some methodological guidance for our own research. Following this research stream, future consequences of present decisions cannot be fully anticipated. However, it is possible to define ex ante the conditions necessary to achieve the solution (i.e., requalify the problem) and to analyze ex post the features not anticipated. Such a situation provides two types of analysis: the first one is a 'pre-revelation' and consists of explaining the phenomena and its consequences without knowing the novelty and what generates the novelty. The second phase of 'post-revelation' consists of explaining what arrives once the novelty reveals its own features and the consequences of such novelty. That explains why we adopted the first type of analysis to understand the future challenges and the second type to explain the historical background, also highlighting the previous analysis.

In order to better understand what is at stake in such innovations, our methods included a large set of interviews with French and foreign researchers directly involved in the progress of this technological paradigm (INRAE Montpellier and Colmar in France, Changins in Switzerland, Geisenheim in Germany, and Conegliano in Italy) as well as with several institutions involved in the development stage (IFV—French Institute of Vine and Wine, Agricultural Chambers, ICV—Cooperative Institute for Wine), the institutions in charge of overseeing the wine chain (FAM—FranceAgriMer, CTPS—Permanent Technical Committee for Plant Selection), nurseries, and grape growers. Such interviews were completed with a literature review, partly grounded on technical research, in order to better understand the research avenues. We have also benefited from the participation in two main workshops (IFV Narbonne and Wine Links Paris) as well as in an internship involving the training of grape growers participating in the adoption of such innovations (ICV Bordeaux).

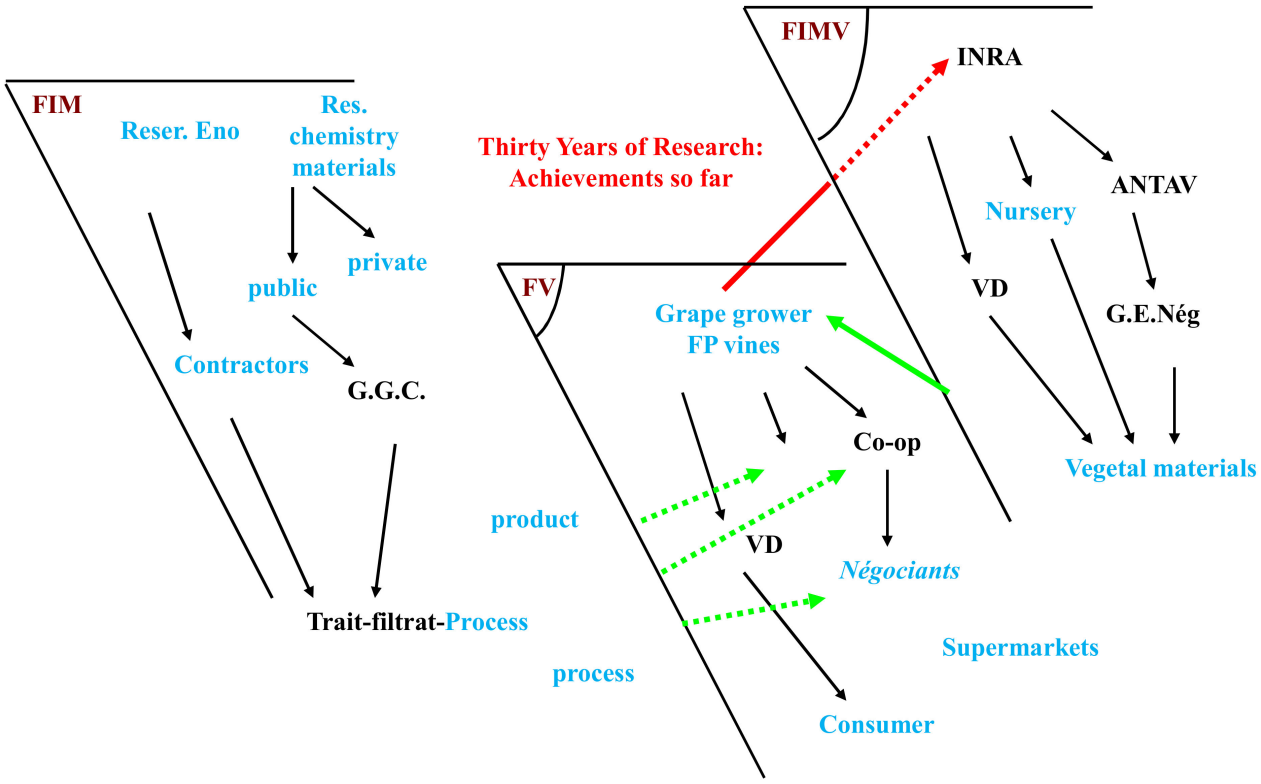

Figure 1. Innovation chains of membrane techniques and plant material in viticulture. Source: authors' own elaboration. Abbreviations: oenological research, chemistry of materials research, G.G.C.: large chemical firms, overall industrialist: conceptualization of machines, filtration process, F.P. wines: production function for wine, VD: direct sales, merchants, Co-op: cooperatives, FIM: membranes innovation chain, FIMV: vine plants innovation chain, ANTAV-ENTAV: national association for improving viticulture, INRA: national institute for agricultural research, G.E.Nég: large merchant nursery firms, grafting sub-contracting processor.

3. Findings

From a historical perspective, the challenges of innovation in plant material concerned more the sanitary and clonal selection and less the creation of new grape varieties [18]. This research avenue transformed the wine chain and contributed to the suppression of the main virus diseases, thus providing the whole world an unprecedented level of productivity and quality. The new grape varieties, at least in France, did not have such impact. Therefore, we will explain this relative failure. The growing societal demand for sustainable development and adaptation to climate change renewed the technological paradigms of grape varietal research, which has renewed the attention of policy makers and researchers to this virtually abandoned trajectory of success.

The central question in this research is: *'Will grape varietal innovation contribute to a more sustainable development and adaptation to climate change?'*. In the following sections, we will discuss the technology status, including its internal controversies, and the institutional and strategic conditions of the innovation chain of plant material.

3.1. The Demand

The spectrum of pesticides available—fungicides and insecticides—ensured up until then good quality of grapes to grape growers and equally protected agronomic yields. The increasing awareness of the need to decrease pesticide use is a relatively recent matter in the wine industry. Grape growers often neglected the risks over their own health [19].

The uniqueness of the wine industry was progressively distinguished from the general criticism of the ecologists by forbidding the use of pesticides for the treatment of wood diseases (Esca) with soda arsenate, which was justified by its consequences leading to frequent

cancers among grape growers applying such a product. Additionally, the increase of legal complaints related to children being mildly intoxicated at school following pesticide spraying in the neighborhoods was backed by the press [20]. Data about the share of pesticide use in viticulture in Europe also contributed to attract stigma to this sector [4] p. 7. Furthermore, two documentaries on this matter targeting Bordeaux viticulture and broadcast on French television—'Cash Investigation' and 'Cash Impact'—gave it a large audience among the general public.

The plan Ecophyto 2018 was established by the French Ministry of Agriculture in order to meet the societal demand. 'Today, the impact of these products which, by definition, act on living organisms, on human health (applicators and consumers), and the environment, is at the heart of societal concerns' [21] p. 2. 'Following the Grenelle de l'Environnement, the plan Ecophyto 2018 constitutes the commitment of the stakeholders—who participated in the elaboration of such plan—to reduce the use of pesticides by 50 percent at the national level within 10 years, if possible. CEPVITI [22], the plan Ecophyto 2018 puts in place the instruments to reduce the dependency of farms on plant protection products while maintaining a high level of agricultural production, both in quantity and quality.' [22] p. 7.

At the same time, the EU published Directive 2009/128/EC about the sustainable use of pesticides. The document 'aims to achieve a sustainable use of pesticides in the EU by reducing the risks and impacts of pesticide use on human health and the environment and promoting the use of Integrated Pest Management (IPM) and of alternative approaches or techniques, such as non-chemical alternatives to pesticides [23]. This directive is directly included in the agricultural part of the European Green Deal and its more general ambition: 'Striving to be the first climate-neutral continent; Climate change and environmental degradation are an existential threat to Europe and the world. To overcome these challenges, the European Green Deal will transform the EU into a modern, resource-efficient and competitive economy…' [24].

The fear demonstrated by some grape growers of being subject to lawsuits, as in the case of asbestos exposure, for not having sufficiently protected their agricultural workers from such risks, has completed their awareness and awakened their attention to all potential research avenues and, of course, the possible contributions of new resistant grape varieties.

Therefore, the decrease of pesticide use in viticulture represents an unquestionable societal demand today. However, considering the technical data sheets and the specialized press, resorting to new grape varieties does not seem to be a miracle solution, at least for the moment.

Generally speaking, climate change has been the subject of much controversy, particularly over its origins and possible solutions at the global level. In viticulture, data on harvesting dates declining since 1981 [25] and the increase in the average alcohol content degree of one unit (vol %) every ten years have confirmed this growing awareness, which has been investigated by ad hoc research programs [26].

3.2. Delay and Its Consequences

The creation of new grape varieties requires a long time and an adjustment to the progress in the new methods for the gene selection. We will illustrate it with a few past examples.

In 1956, in France, researchers from the INRA in Montpellier set up a research program for varietal creation. The purpose of the program was to create new grape varieties at least 'equivalent' to existing varieties, in particular the dominant grape variety of that time, Carignan, i.e., that these grape varieties had to reach at least the same agronomic yield level.

Indeed, the yields in table wines were the main 'cost divider' and therefore a factor to ensure income. The varieties had to be 'à port dressé' (upright); i.e., the canopy management did not require the establishment of a vertical trellis ('*palissage*'). The canopy system was established in 'gobelet' (open-center or shrub shape), because this method was widespread in the south of France and was less expensive. Early ripeness of grape

happened because of the conditions in the south of France: each two years over five years, the harvest was held during and after the autumn rains, and it frequently suffered damages from gray rot (Botrytis cinerea). In addition, if this grape variety was less sensitive to the main diseases (downy mildew and powdery mildew), that was also a benefit. Finally, the organoleptic qualities had to be at least equal to if not better than the existing varieties.

The research avenue chosen was the intraspecific hybridization; i.e., crosses were made within *Vitis vinifera* varieties without crossing with other species such as American or Asian Vitis. The main explanation for this fact was justified by the fact that French law banned most of the interspecific hybrid grape varieties, resulting from post-phylloxera investigations, whose wines were qualified as low quality (it is important to notice that in the wine register finished in 1960, approximately half of the French vineyard surfaces were planted with direct-producer hybrids (usually known in the past as *French hybrids* or *French-American hybrids*)). In fact, in order to accentuate this distinction, the breeders designated these grape varieties as '*métisses*' (i.e., half-breed) and no longer hybrids (the use of hybrids in viticulture is common outside Europe but not in the Europe). Nowadays, the definition of the classification of grapevine material used still requires some harmonization and new international standards. Several projects of definition and classification are under discussion in the OIV working groups. Those projects involve the process for clonal and polyclonal selection of vines (I), and the production, certification, and trading of viticultural plant material (sanitary and genetic issues) (II) [27].

This research program was partly successful. It led to the creation of new grape varieties with various dissemination rates. As an example, the grape Marselan is a cross (Cabernet × Grenache) established in 1962; the second stage of 12 plants was reached in 1971; stage 3 of 150 plants was reached in 1974. The micro-vinifications held from 1978 to 1982 recognized the high qualitative level of the new grape. However, the opinion of wine professionals was negative, estimating that the yields were quite low. The INRA continued the experimentations and registered the grape in the French catalog in 1991. Twenty-eight years later, in 2019, this grape variety represents in Languedoc-Roussillon 5040 ha, i.e., 2.0% of the surfaces planted with red varieties surfaces in the region. In France, Marselan accounts for 6426 ha, i.e., 1.3% of the black varieties' vineyard surfaces in 2019 (Direction Générale des Douanes et Droits Indirects, extraction from the Cadastre Viticole Informatisé).

This program launched in 1956 produced five significant grapevines: the Marselan N; the Caladoc N; the Chasan B; the Chenason N; and the Aranel B. However the low dissemination of these grape varieties following twenty-eight years of development, i.e., 65 years after the launch of the research program is really limited. We could also add the example of Clarin B., which was obtained by the INRA in 1953 and registered at the French catalog of grape varieties but covering only 6 hectares of vines.

3.3. How to Explain the Relative Failure in the Diffusion of Such Innovations?

The reasons of such failure rely on causes specific to the technological paradigm and reasons related to the institutional environment defining the boundaries of the market conditions.

3.3.1. The Limits of the Technological Paradigm

Two major elements explain the difficulties of dissemination: the choice of crossbreeding (*métissage*) and the time to reach results being out of step with the needs of the economic environment 30 years later.

French researchers having chosen crossbreeding (*métissage*), that is to say intraspecific hybridization, which was expected under the economic and regulatory context of 1956, deprived themselves from incorporating genes of resistance to diseases or to some climatic conditions not included in the *Vitis vinifera* species but present in other species of genius Vitis. Researchers from other European countries have, from their side, adopted another strategy (i.e., a different paradigm) by making interspecific crosses and later carrying out 'backcrosses'; i.e., what the geneticists designate today as 'introgression'.

By introducing the *Vitis vinifera* genes, after a long period, researchers successfully obtained grape varieties with a high percentage of *Vitis vinifera* genes (≥99%) (this issue was discussed by the professor of ampelography Jean-Michel Boursiquot [28], pointing out the complexity of evaluating this percentage and, therefore, he proposes to maintain the qualification of hybrid for these new varieties), i.e., wines with high quality levels identical to *Vitis vinifera*: the difference being the resistance factors except for *Phylloxera*, but this problem was solved out through grafting. This line of research has been followed in the research carried out in Germany and Switzerland ('The selection programs developed in France since 1974 adopted the hybridization between *Vitis vinifera* and *Muscadinia rotundifolia*. There is therefore a deliberate choice to pursue the improvement of old hybrids, contrary to the research choices in Germany despite the interdiction of the cultivation of hybrids in the country since 1935. Several resistant grape varieties created in the 1970s were authorized for planting in most German *landers*, in particular the grapes that included the grapevine Regent—a cross between Chambourcin and Diana (Sylvaner × Muller-Thurgau)—and the grapevine Phoenix—a cross between Villard white and Bacchus [(Sylvaner × Riesling) × Muller-Thurgau].' [29], pp. 178–179).

The second explanation concerns the gaps between the goals of the research and the economic conditions faced by those grape varieties thirty years later under new market conditions (see Table 1).

Table 1. Evolution of the economic environment of the wine chain in Languedoc-Roussillon (1956–1986).

1956	1986
High yields	Overproduction–Grubbing up of vines–Mandatory distilling for high yields–Quality = low yields
Upright variety–*Gobelet*–manual harvest	Mechanical harvest–*Palissage*–Trellising
Early maturity	Global warming
Importance of the table wine market	Market for varietal wines
Novelty without reputation	Reputation of the main traditional grapevines in the Appellations (PDO and PGI)
Vinifera without resistant genes to fungal diseases	Resistant genes in non-*Vitis vinifera*
	World competition driven by popular grape varieties
	New grape varieties excluded from *appellations*
	New grape varieties long excluded from *vin de pays (protected geographic indications)*

Source: Authors.

Indeed, the economic conditions have considerably changed in 30 years. From a period of relative scarcity during the creation of the Common Market, the European Union faced a structural overproduction linked to the vine plantings in the 1960s, an increase in agronomic yields, and mainly the drop of wine consumption in all wine-producing countries. Thus, the policy was oriented toward quality wines, wines with geographic indication (*vin de pays*), and wines with *appellation d'origine*, which were characterized by restrictions in yields and the wide inclusion of the main qualitative international grape varieties known from traditional AOC varieties.

The canopy management system changed considerably in Languedoc, both because the use of traditional grapevines coming from other appellation areas and mainly after 1972 with the introduction of the harvest machine. The first harvest machine in Languedoc was a Chisholm-Rider, imported from the United States in 1972 for the vineyard in Grau du Roi (South of France) [30]. Global warming gradually, from 1981, according to Champagne statistics, brought earlier the harvest date. Early ripeness became a less important factor.

The market for varietal wines took over in the early 1980s and became more and more important with regard to the market for table wines. This market was based on

the reputation of the main international grape varieties, i.e., Cabernet Sauvignon and Merlot—for the reds—and Chardonnay and Sauvignon, for the whites. The grapevines Marselan and Chasan were not known.

3.3.2. The Institutional Limits

The law of 6 May 1919, redefining the rules for the AOC—*Appellation d'Origine Contrôlée*, is based on the 'local, loyal, and constant' practices. This definition excludes new grape varieties. The regulation assumes that those wines elaborated with traditional cultivars present the best quality profiles, the best reputation, and the best market values (now redefined as PDO—*Protected Designation of Origin*). However, we should notice that very recently, the institute INAO authorized the introduction in the Bordeaux region of the production of wines with some French grape varieties, old and 'new', and foreign below the limit of 10% of the total wine in a bottle, which facilitates the experimentation and learning (red grapes: Arinarnoa obtained by the INRA in 1956, the Castets originary from the southwest, and the Marselan obtained by the INRA in 1961, and the Touriga Nacional, originary from Portugal. White grapes: Alvarinho and Liliorila [31].

Even in the case of the largest French geographic indication Pays d'Oc, which established its reputation on varietal wines, it required many years to finally accept these new varietals in its own specification (*cahier de charges*). Later, it was followed by the appellations (AOCs): the grapevine Marselan was only authorized in Côtes du Rhône in 2010, at the maximum rate of 10% (blend); the grapevine Caladoc is still being tested for this appellation [32].

However, very recently the situation was unblocked: 'The Common Agricultural Policy will give the specifications of the appellations the possibility to integrate non Vitis vinifera varieties' [33].

Indirectly, the impossibility of using planting rights to plant vines to produce table wines until 2015 did not foster the dissemination of this grapevine in the wine category where it was positioned initially (wine with no geographic indication). In addition to the lack of vine-planting rights, and following the same policy logic, another barrier to the dissemination of the new grape varieties was the unavailability of subsidies within the Common Market Organization framework to restructure those vineyards.

More broadly, in France, the natural rate of vineyard renewal is approximately 2.5%/year with an average lifespan of forty years. The choice of the variety is an important decision impacting the long run. New grape varieties that compete with well-known varieties and new trends require a long time to develop.

The institutional trends continue to progress. It is important to refer to a recent OIV resolution: OIV-VITI 652-202, titled 'Recommendations concerning the selection and breeding of grapevine varieties for their adaptation to the effects of climate change.' [34].

The above recommendation calls for strengthened international collaboration between scientific institutions to support the exchange of information, to improve knowledge on varieties, to coordinate research and breeding programs, and to recover and conserve genetic resources from the vine.

Knowing that the OIV has become the benchmark for standards at the level of the European Commission, we can only note the general awareness of the importance of this issue.

3.4. The New French Research Programs

The return to interspecific hybridization in France: pioneering programs and recent programs.

3.4.1. Bordeaux: Roger Pouget

Roger Pouget, research director at the INRA Bordeaux, returned to interspecific hybridization in the 1990s. He created two new grape varieties: the 8502 cross of Fer Servadou and a white hybrid as well as a cross of a Riesling and a white hybrid. Although

of a correct quality level, these grape varieties were not selected. Then, the program was practically stopped. The evaluations were repeated more recently for four crosses by the research group on organic agriculture—GRAB.

3.4.2. Montpellier: Alain Bouquet

Alain Bouquet, research director at the INRA Montpellier, launched the research program in 1974 by seeking in *Muscadinia rotundifolia* genes for resistance to numerous parasites and diseases, including powdery mildew and downy mildew. Then, he applied the classic method of backcrossing to traditional quality vinifera grape varieties, and those grapes exhibited a high level of resistance to powdery mildew and downy mildew [35]

The results of his research were almost destroyed when he died. Fortunately, they were preserved by Professor Alain Carbonneau and then moved to the INRA facilities in Colmar. He also obtained a new rootstock, the Nemadex Alain Bouquet, which is still under evaluation ('*From 1985, the selection focused on the resistance to the grapevine fanleaf virus and transmitted through the Xiphinema index nematode. The INRA stations of viticulture in Montpellier and nematology in Antibes focused their research on obtaining a natural resistance to the vector derived from the specie. This program resulted in the selection and experimentation in 1999 of a grape variety showing in the field a high degree of resistance to the virus*') [30], p. 176.

In recent years, the investigations of Alain Bouquet continued in the south of France under the leadership of the INRA Pech Rouge with two main purposes: to examine the long-term resistance of the new varieties (I) and to define quality criteria in winemaking (II) [18].

3.4.3. Colmar: The Resdur Program

In the organization of French viticultural genetics at the INRA, the Colmar team took over from 2000 the continuation of the research initiated by Alain Bouquet in Montpellier and Jean-Pierre Doazan in Bordeaux. The ResDur program (for RESistance DURable) retakes the varieties developed by Alain Bouquet with the resistance genes from Muscadinia, which he combined with the German grape varieties—Regent and Bronner—whose resistance originates from American or Asian Vitis [36].

The objective of this program is to take into account the results of studies that showed the addition of several resistance genes, which are designated as pyramiding and contribute to improving the overall resistance and decreasing the risk of bypassing the resistance. This program also benefits from the advances in molecular biology: in particular, the use of molecular markers to identify resistant vines at very early stage of seedlings. This makes it possible to foster backcrosses (introgression) and reduces the lead time from 25 to 15 years.

The first crosses were made in the first ten years of the 21st century three times. The first crosses are at the final stages of selection, i.e., those being able to confirm the agronomic, technological, and environmental value (VATE) [37]. Twelve grape varieties were candidates and were considered for registration in the French catalog by 2016. The other new grape varieties candidates should be registered in the French catalog from 2020 to 2023 [38].

3.5. The Arrival of Foreign Grape Varieties

The professionals in the south of France (Hérault) engaged in an original approach under the Cooperative Institute for Vine and Wine (ICV) and the regional wine observatory, funded by the local authorities (Département de l'Hérault). A first mission for the study of grape varieties resistant to fungal diseases was carried out in 2011 in Switzerland, Germany, and Alsace.

Then, the wine professionals discovered that the Italians, the Swiss, and the German had listed or were about to include in their national catalogs some grape varieties resistant or more or less tolerant to downy mildew and powdery mildew. In the other locations, they already produce and sell wines from these grape varieties.

3.5.1. Switzerland

Two Swiss teams selected grape varieties resistant to pests and diseases: one at Agroscope de Changins and the other at the nursery Borioli-Blattner, a private entity.

Changins

The selection focused on resistance to Botrytis started in the 1960s for the white varieties and in 1970s for the reds. The originality of this resistance is that it is not genetic but morphological or biochemical through the production of a toxin lethal to the fungus.

The resulting Gamaret (Gamay X Reichensteiner)—an intraspecific cross—was registered in 1990 and was widely planted. It was registered in the French catalog after experiments in the Beaujolais area. It developed rapidly in Switzerland, reaching 424 hectares in 2014 (over 15,000 ha of total surfaces), i.e., accounting for 5 percent of red grape varieties planted [39,40]. Other varieties were developed such as the Garanoir or Garlotta (1981).

This area of improvement continued through crossbreeding (métissage): Merlot × Gamaret (MRAC 1087 and 1099), Cabernet franc × Gamaret (MRAC 40), Humagnerouge × Gamaret (MRAC 1626), Nebbiolo × Gamaret (MRAC 1817).

It was only after 1996 that the research program to diseases and pests began: downy mildew and powdery mildew. The trajectory adopted was the interspecific hybridization with genes of resistance. The sequencing is classic with 55 different crosses, 896 individual plants retained, after biochemical tests, 33 varieties (30 red, 3 white) selected at the 20 plants stage with vinification, 13 varieties survived through extensive trials and, finally the Divico was registered (Gamaret × Bronner)—an intra–interspecific cross—in 2013. It is the first multi-resistant grape variety: resistant to mildew and rot, showing low sensitivity to powdery mildew, with high qualitative potential for varietal wines or blends, producing Gamaret-type wines with dark purplish notes that are rich in color. The bouquet is dominated by black fruits and berries. The wine is rich in tannins, with soft and coated tannins that are complex on the palate [39].

The main European countries that were concerned about the plant-breeding process of resistant grape varieties collaborated by exchanging the plant material. The Weibauinstitut in Fribourg has made it possible to use its tolerant varieties, such as the Bronner [41]. The research center of the INRA in Colmar exchanged its plant material, carried out joint crosses, and carried out genotyping of resistant factors. These varieties could be jointly owned with the INRA and thus disseminate more quickly in France after the anticipated VATE (Agronomic, Technological, and Environmental Value) trials.

The Swiss do not use the qualifier hybrid: instead, they use the term PIWI, Pilzwiderstandsfähig (resistant to fungal diseases) [42]. This term benefits from a common label for the promoters of these resistant grape varieties (cf. Pugibet). The Swiss go even further; the grape variety Johanniter (resistant grape obtained from Fribourg) is listed in the Swiss catalog as *Vitis vinifera* [43,44] (see the tribune of Professor Jean-Michel Boursiquot [28]).

The Nursery Borioli-Blattner

In the great tradition of the first half of the 20th century, a nurseryman and a private breeder selected varieties that are tolerant and/or resistant to downy mildew and powdery mildew. Thus, they have created several new grapevines: Pinotin, Cabertin, Cabernet Jura (reds), and the Cabernet Blanc (white), some of them are officially registered.

Although distributed in Switzerland, Germany, Italy, and Central and Oriental European Countries, their distribution remains very limited. However, the Domaine de la Colombette (Béziers, France) anticipated the availability of these grape varieties in France.

3.5.2. Germany

German varietal creation took place in several institutions on a constant basis, combining intraspecific and interspecific hybridization. Grape breeders created new varieties and for those meeting the demand, their distribution was backed without making any reference to this origin (hybridization).

It is worth mentioning that according to the VIVC (Vitis International Variety Catalog—available online at: www.vivc.de, (accessed on 6 August 2021)), German inter–intraspecific (or intra–interspecific) hybrids are classified as Vitis vinifera cultivars.

Dornfelder

Dornfelder is also designated We S-341 or Weinsberg S-341, from the name of the place and the Institute where it was created by August Karl Herold, in 1955 (Staatliche Lehr-und Versuchsanstalt für Wein-und Obstbau Weinsberg). Unlike the Regent, it is half-breed (*métis*), an intraspecific cross (see Figure 2). Its color initially made it used in addition to paler wines. We can clearly say that it participated in the reconquest of red wines in Germany.

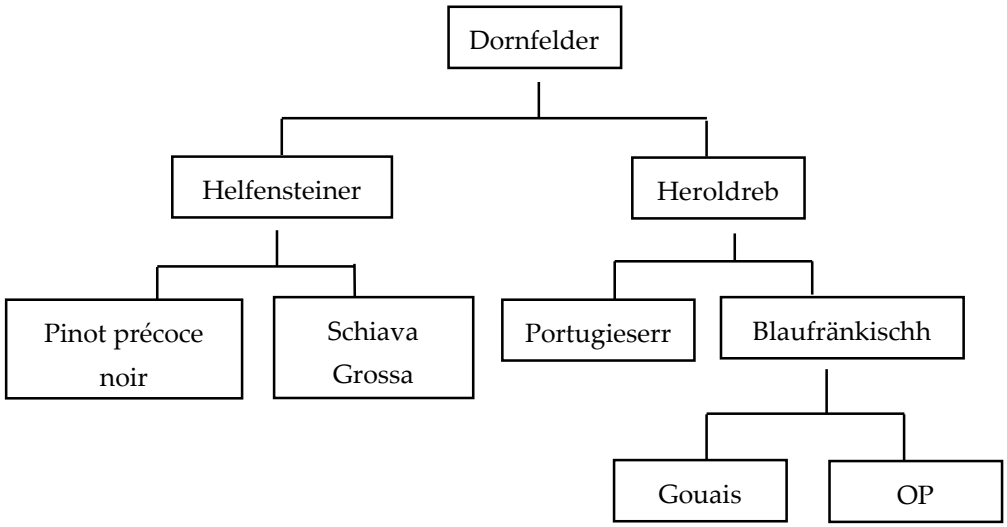

Figure 2. The genealogy of the grapevine Dornfelder. Source: [45].

From 100 hectares in the 1970s, it reached 7332 hectares in 2020, i.e., 21.9 percent of the areas under red grape varieties, placing it on the second position after the Blauer Spätburgunder [46].

Acolon

This variety of red wine has the same provenance as the Dornfelder but was obtained at a much later stage based on a cross of Lemberger and Dornfelder. From 100 hectares in 2000, it occupies 459 hectares in 2019, i.e., approximately 1.3 percent of the vine surfaces in Germany planted with red grape varieties.

Regent

Regent was created in 1967 from the crosses of Diana (Sylvaner × Müller-Thurgau) and Chambourcin, by Prof. Dr. Gerhardt Alleweldt at the Institute for Grapevine Breeding of Geilweilerhof (Palatinat, Germany), Regent is 80.06% vinifera genes. Regent passed successfully all the technical and organoleptic tests and shows a high qualitative potential. The first Regent plantings were established in 1985, in some experimental grape farms. The grapevine has been protected since 1993 and two years later was added to the wine register.

Since 1996, the German authorities listed it in an equal way as the traditional Vitis vinifera grapevines and, since then, it was officially recognized as able to produce Qualitätswein (quality wine, *appellation d'origine* in Germany). The Regent was planted in many European vineyards. We can obtain a dry and soft wine grown under the severe weather conditions in Northern Europe. The color is an intense light red, because this grapevine is a dyer (=*teinturier* cultivars, also designated as dyers). It should be noted that the Regent, a grapevine with monogenic resistance, saw its resistance 'bypassed' in 2010 by a strain of mildew, which was also the case for Bianca [47].

Today, the new grapevine is available in almost all German wine regions. The surface of Regent expanded from 70 ha in 1997 to 2150 in 2005. However, the expansion de-creased a little bit in the last decade and stabilized around 1722 ha in 2020, i.e., 5.1 percent of German red grapevines. The plantings are concen-trated mainly in the Rheinland-Pfalz (1363 hectares in 2017). Figure 3 shows the genealogy of this grapevine and clearly high-lights the perseverance of its breeders who continued to improve hybrids from previous generations.

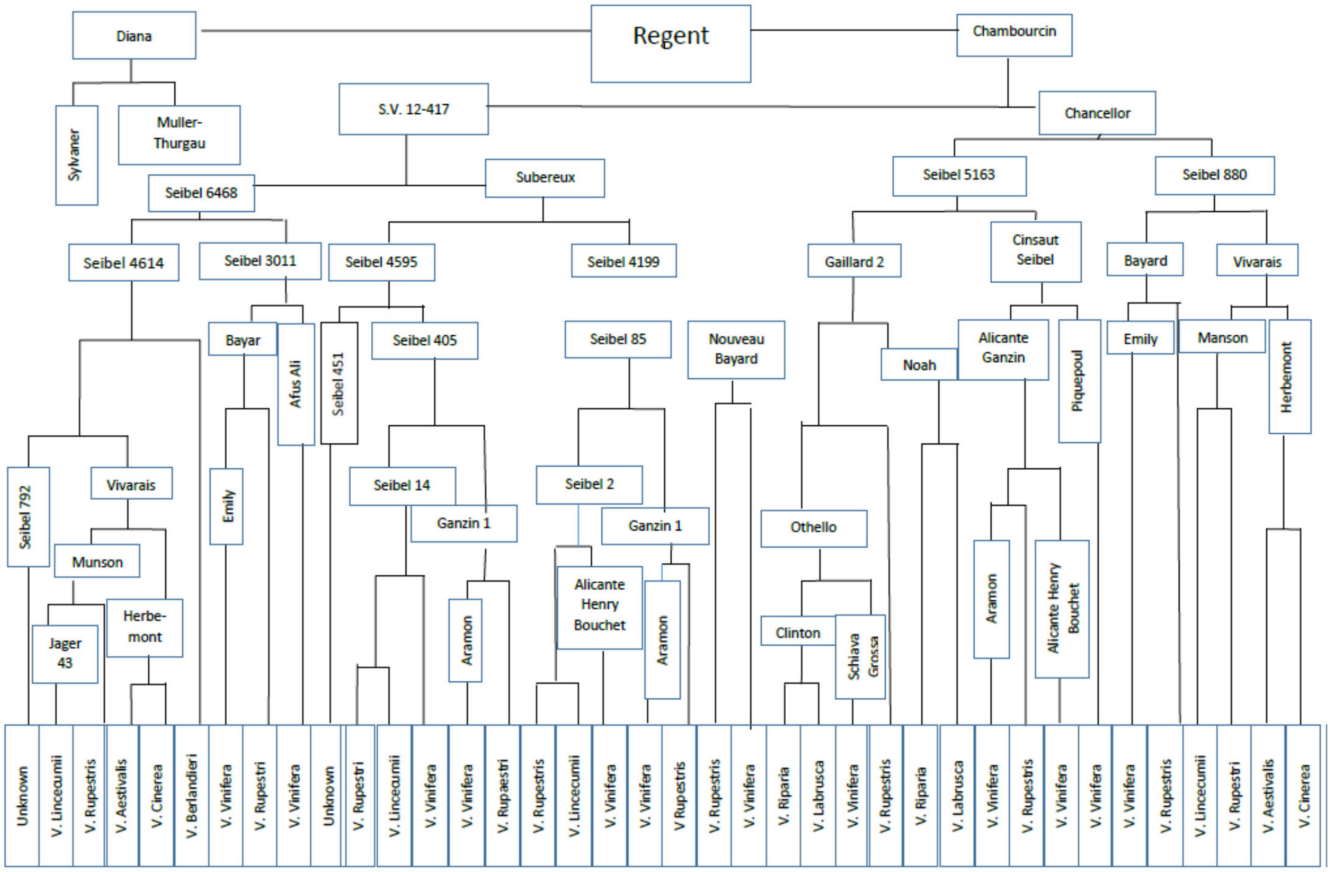

Figure 3. The genealogy of grapevine Regent (Gf. 67-198-3). Source: [48]. Figure: Pedigree tree of 'Regent' and its progeny. Purple: tested genotypes; green: tested traditional Vitis vinifera va-rieties; red: tested offspring of 'Regent'; grey: most likely extinct or not available for analysis. Berry color (background) and flower sex are indicated in squares. Confirmed resistance loci against Erysiphe necator (light green) and Plasmo-para viticola (light blue) are indicated in ellipses. Loci Rpv10 and Ren1 were not found.

Regent is a red wine grape, a *blanc de noir*, which has the property of being re-sistant to the most significant fungal diseases, which contributes to a significant de-crease of the grapevine protection treatments of more or less 80%. Professionals recog-nize its qualifying and coloring properties.

Kerner

The 'little brother' of Riesling meets all the quality levels: robust table wine, Spätlese, and even qualitative Sekt. Trollinger was not able to (and it should not) have a significant influence concerning the color. It was August Herold, a citizen from Lauffen and Neckar, in the Wurtemberg that in 1929 was able to cross Trollinger and Riesling. The new grapevine was designated 'Weißer Herold', and afterwards, it was named Kerner, as a reference to the poet and Doctor Justinus Kerner (1786-1862). The cross We S 25–30 promoted at the request of the Research Institute from Weinsberg obtained the grapevine certification in

1969. In 2020, Kerner accounted for 2257 ha of vine surfaces in Germany (i.e., 3.4 percent of white grape surfaces).

Fribourg

Already in 1978, Becker and Zimmermann [49] announced the research avenue chosen to introduce resistances to fungal diseases in the new varieties created.

The genealogy of these varieties dates back to 1860. Figure 4 reviews all the contributors leading to Fr73-6 resistant to *Plamopora viticola* (downy mildew) in 1973. In the 1980s, Nortber Becker continued the research initiated in 1950 at the Viticultural Institute (Weinbauinstitut) in Fribourg and created several red grapevines with a good quality level and low sensitivity to fungal diseases. Among those grapevines, we can identify four groups: (a) dyer type; (b) the fairly neutral type that can be used to improve color, tannins, and the degree of alcohol content; (c) fruit type quite similar to Pinot noir or to other known grape varieties; (d) the Mediterranean tannic type reminding the Cabernet Sauvignon. Those grape varieties were made available to professionals. That was the case of grapevines planted by Vincent Pugibet [50] at Domaine de La Colombette (Béziers, Hérault, France) (Cf. infra).

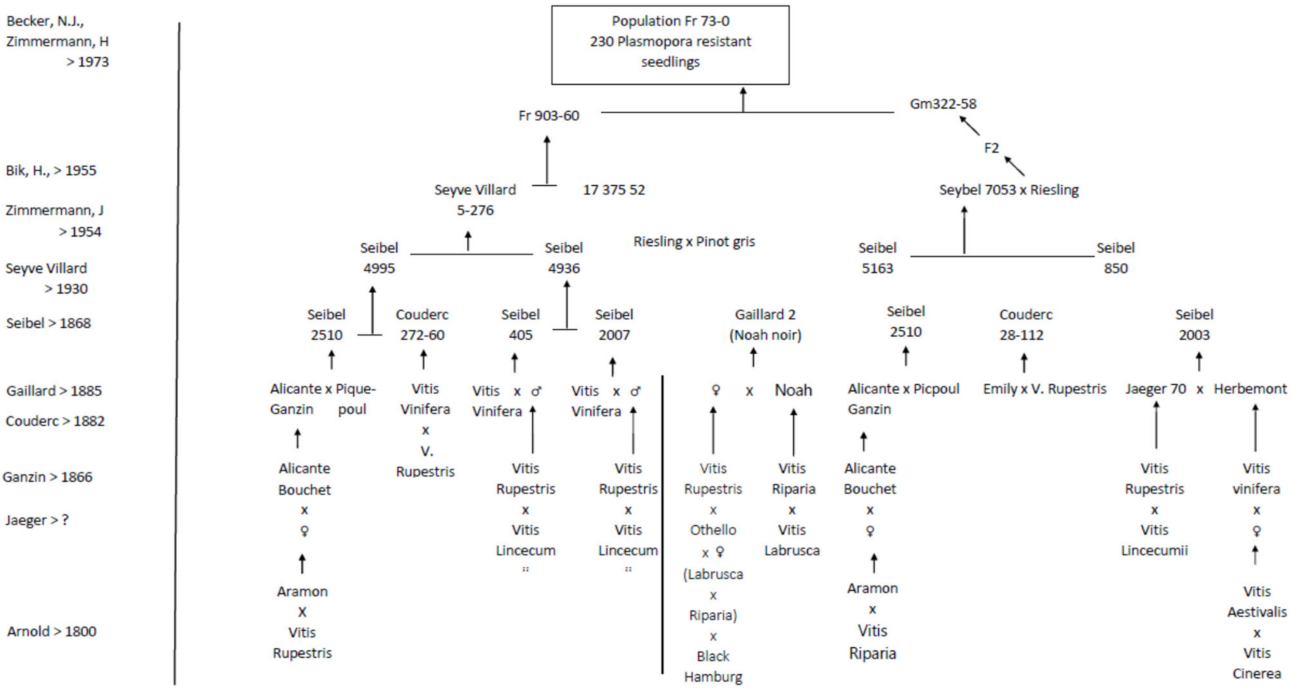

Figure 4. Genealogy of the population Fr73-6. Source: [49].

3.5.3. Italy

The acceptance of resistant varieties in Italy is not an easy feat. It took thirty years for the resistant grape varieties obtained in Fribourg to be listed in the Italian national catalog in July 2013 and to be authorized in Veneto, Trentino al Adige, and Lombardy [51]. Those authorizations depend on the government in each region. These eight varieties are Bronner, Cabernet Carbon, Cabernet Cortis, Hélios, Johanniter, Prior, Regent, and Solaris.

At the Istituto di Genomica Applicata (IGA) from the University of Udine, the research resumed at the start of the 2000s. The selection was based on the crossing of local and international grape varieties such as Tokay, Sauvignon Blanc, Merlot, Cabernet Sauvignon, with German and Hungarian grapevines already 'introgressed' and known for their resistance: Bianca, Regent, or the 20-3.

Ten resistant grapevines were listed in the Italian catalog: Fleurtai, Soreli, Early Sauvignon, Petit Sauvignon, Sauvignon *doré*, Petit Merlot, Royal Merlot, Petit Cabernet, Royal

Cabernet, and Julius (cf. see hereafter the debate about the names of these grapevines). VCR (Vivai Cooperativi Rauscedo), a cooperative of nurseries and a leader in Italy, tested new grape varieties resistant to frost and to fungal diseases in collaboration with the University of Udine (mono and polygenic) [52]. VCR's experimental cellar makes it possible to vinify up to 400 micro-*cuvées* per year and to carry out the oenological evaluation of the new selections [53]. The new varieties are typical-like Chardonnay, Cabernet, and Sangiovese. Thirty-four grapevine hybrids are still being tested.

The listing is still met with skepticism from the state administration, which is appalled by the term interspecific hybrid which, in principle, cannot be grown for wine production. Therefore, it must be demonstrated that the content of malvidin 3.5-diglucoside and that of methyl alcohol are lower than European standards, as well as the absence of strawberry flavor. The VCR catalog and test report show that all these varieties broadly meet these criteria [51]. In September 2015, eleven grape varieties entered the Italian catalog [54,55].

3.5.4. Eastern and Central European Countries

These countries have had their own production of interspecific or interspecific hybrid varieties. Such countries participate in European vine improvement programs.

From a historical point of view, we can cite the case of Bianca. It is a complex interspecific cross between 12,375 Seyve-Villard (2 Eger) and Bouvier, a grape variety of Austrian origin, which was obtained in 1963 in Hungary by Csismazia Jozsef and Bereznail Laslo. Bianca's resistance was overcome in 2010 by a strain of mildew, similar to Regent. Widely developed in the Central and Eastern European countries, Bianca is practically unknown in France [56].

3.5.5. The World Research

We did not take a comprehensive review of the global research in our investigation. The following publication '*Grapevine Breeding Programs for the Wine Industry*' [57] reports the work in progress and is an essential reference on this topic. All the main producing countries are active in this area. Those research studies are starting to be taken into account in the three main producing countries.

3.6. Scientific Controversies between Monogenic and Polygenic

In an interview to *La Vigne* [58], Mr. François Houllier, deputy CEO at the INRA, clarifies the position of the institute about resistant grape varieties developed by Alain Bouquet, the first that could be released in France.

'Thanks to the pioneering work of Alain Bouquet, we have plant material with excellent resistance to powdery mildew and a high level of resistance to downy mildew. But the supposed monogenic character of these resistances represents a danger for their durability. In theory, the risks of bypassing are increased with monogenic resistance. Downy mildew is a fungus capable of mutating very quickly to bypass resistance . . . This is the reason why, in 2000, we developed a selection program for resistant grape varieties, which have at least one other resistance gene, in addition to those used by Bouquet. The polygenic character guarantees greater durability of resistance' (free translation from French).

This controversy among scientists is essential to understand the dissemination delays in France. The public research (INRA) fears the release of grapevines whose resistance would be quickly bypassed and which would suppress the interest of this gene. This scientific risk is coupled with an economic risk because the varieties released would no longer meet the expectations of professionals long before their normal lifespan.

The *French Institute for Vine and Wine* (IFV) would be in favor of a supervised distribution of Alain Bouquet's varieties, with some precautionary treatments. The precautionary principle clashes here with the objective of a rapid response to social demand.

The INRA's policy comes up against the pressure of these same professionals. Indeed, 'resistant grape varieties listed in the catalog of one of the EU Member States could be listed in the French catalog without additional experimentation in France. This is the unanimous

request of the professionals, meeting for the first time on Wednesday, 13 January 2016, as part of the working group create to review the draft text on the classification of varieties and experimentation' [59].

3.7. The Battle for Designations and Labeling Is Not Solved

New resistant grape varieties have been almost absent from main producing countries [33]. In this race to adopt new resistant grape varieties, and after having solved the question of the term 'hybrid', a new issue emerged related to the names adopted for the new varieties. In fact, the new Italian grape varieties launched by the cooperative VCR, in close association with the University of Udine, were launched with a double designation, one of which is a previous name of a pre-existing widely known grape producing quality wines. Thus, the following new grape varieties are available in Italy: Merlot Kanthus, Cabernet Volos, Sauvignon Kretos, Cabernet Jura, and Cabernet Cortis.

On the one hand, public authorities want to protect consumers and not to mislead them by signaling quality with those new designations. On the other hand, the experiences of new grape varieties (*métisses*) during the 1980s, rejected by the promoters of varietal wines, drew the attention of wine professionals who were interested in benefiting from the notoriety of pre-existing high-quality grapes. The idea behind these designations is that it is more or less the same or an equivalent variety to which resistance to fungal diseases has been added.

'*As long as the variety has the characteristics of a Merlot or a Cabernet, I do not see why, it could not bear the name*', estimates Bernard Farges from the Bordeaux Wine Council (CIVB). A similar position was also defended by Jacques Gravegeal, president of the ODG of Pays d'Oc (PGI wines) [60]. We should note that the ODG (*Organisme de Défense et de Gestion)* of the protected geographic indication Pays d'Oc is specialized in the varietal wines, accounting for more than 6 million hectoliters produced every year. This position preserves their future.

3.8. The Legislation

Both European and French regulations provide a very precise and constrained framework for the various activities related to the creation and distribution of resistant grape varieties [60,61].

The first fundamental issue is the distinction between the registration of a variety and its classification, particularly since the meaning attributed to these concepts has changed recently. Registration is a French concept; classification is a European concept. Everything that relates to the multiplication and distribution of plant material depends on the listing (registration) in the catalog. Everything that concerns the planting of vines for the production of wine comes under the classification.

Although the regulations are European, the catalog is managed at the national level. A 2008 regulation (*Arrêté* from 21 March 2008, approving the technical regulations for examination of grapevines for their registration to the Official Catalog of species and varieties (JORF n°0078 of the 2 April 2008, p. 5540)) defines the technical registration rules. Three verifications are carried out. The first is the VATE—technological, environmental, and agronomic value. The second is the DHS—distinction between homogeneity and stability. The third one is the name. The procedure lasts five years. Derogations are possible.

The classification wine varieties, defined by the regulation of the new Common Market Organization of 2008, also make it a national competence. In France, the classification is likened to list A1 in the catalog. Before 2008, the grape varieties intended for the production of table grapes were classified at the national level, while the wine varieties were classified at the departmental level in recommended or authorized categories. Today, there is only one classification, the list of which is updated every year only for wine varieties. The distinction between authorized/recommended grape varieties disappeared.

The national catalog (A1 list) includes around twenty old hybrid grape varieties without any planting restrictions. Foreign varieties listed in the catalog of at least one European

Union catalog may be used for experimental purposes. Such permission is a derogation from the classification. However, these grape varieties are not eligible for subsidies when restructuring the vineyards. The new varieties obtained in France by the INRA are not registered and are subject to VATE tests on small areas. Varieties obtained outside the European Union are subject to quarantine and follow a registration protocol. Experimental grape plantations must be declared to the public agency FranceAgriMer and be subject to technical monitoring by a competent body. Planting vines can only be implemented if someone has the rights to plant (planting authorizations). The wines produced from such vines can only be marketed in the wines without geographical indication (no PGI) (i.e., in a category similar to the former table wines) (For a detailed analysis of the new planting authorization regime, see [62]).

List A1 includes the grape varieties whose plants can be marketed within the European Union and which are eligible for the wine classification in France. List A2 includes grape varieties whose plants can be marketed with the European Union but which are not eligible for classification in France. In other words, a French nursery can multiply a German grape variety, but this grape cannot be cultivated in France.

The European Union is considering the harmonization of national catalogs with the idea of creating a single unified catalog, which would promote the dissemination of grapevines in Europe. The classification would allow the introduction of foreign grape varieties not listed in the national catalog [3].

In fact, to date, the conditions for the distribution of resistant or partially resistant foreign grape varieties among the 300 included in the ICV catalog is very limited. Thus, only the Domaine de la Colombette (Béziers) has embarked direction. The estate planted 30 hectares of 'experimental' vines with 28 resistant grape varieties, using and purchasing planting rights. The estate was not subsidized; it is subject to technical monitoring and sells their wines as wines without geographical indication. The solution found to better promote these wines was to create a brand 'Au creux du nid' and to highlight the PIWI label and the gold medals awarded during the International PIWI competition [42,50].

3.9. Stakeholders' Strategies

Each stakeholder or stakeholder category of the wine innovation chain positions itself and follows a specific strategy in its search for profit or satisfaction of public interest.

3.9.1. The Public Research in France

Public research applied to plant breeding aims to meet societal demands as best as possible. Legitimacy depends on the needs, converging between winegrowers and citizens, whether they are consumers or not. The delays are important but shortened by the new molecular methods. Divergences appear linked to scientific controversies related to the monogenic or polygenic resistance. The strategy adopted by public authorities prioritizes the safety associated to polygenic resistance.

In addition, part of the funding for applied research is sourced from royalties collected from newly created varieties. It is likely that in this context, the new French grape varieties will be preferred to foreign grape varieties, thereby supporting the French nurseries driven by the demand. These two issues add up without questioning the reality or the relevance of the controversy.

3.9.2. Research Developed from Other Wine Countries

We have seen that research in other countries uses the same methods. International collaborations are increasing. Each country, region, or institute has its own strategy, in particular in the financing of the research work and the beneficiaries of the exploitation of the research outcomes. However, the essential issue is the adaptation to the ecological, climate, and economic conditions of the regions where it is based, while retaining the possibility of a strong international distribution if the qualities of the new grape variety allow it. We did not extend our survey to Central and Eastern European Countries on

the theme of varietal creation, although we started our questioning during our meetings at the Keskemet Institute with the framework of the EU's Phare Programs in 2000 and 2005 and the investigations on viticultural transition in Romania market by an unexpected development, at the time, of hybrid varieties (see [63]).

3.9.3. The Development Entities

The French development organizations are playing their role and rebounding on the wave promoted by an increasing societal demand. The regional Agricultural Chambers, through their advisory function, set up VATE tests which will enrich the application file before registration—which is no longer established at the Department level—and have specific technical information to transmit to grape growers [64].

The ENTAV–National Technical Organization for Viticulture continues the R&D with the INRA on the adaptation to climate change, including clonal selection. Both organizations play a role by providing plant material to nurseries. The distribution of the profits, derived from licenses, between the INRA and ENTAV is not disclosed.

The ICV–Institut Coopératif du Vin, a co-op organization, took the initiative of raising awareness in France of the value of resistant grape varieties. This institute organized the first international study trip [43] and additional investigations of resistant grapevines, leading to a book of reference in 2015. In this way, the institute prepared to anticipate changes required in oenological practices for the vinification of those grapevines [44].

3.9.4. The French Nurseries

Only a single nursery company has embarked on the supply of propagating material for resistant foreign grape varieties, in connection with the Domaine de la Colombette (Béziers, south of France) project. Producers, in particular from Bordeaux, are awaiting authorization to plant such grapevines. To date, due to the lack of orders, it is difficult to anticipate the 15 to 18 months necessary for the production of the necessary graft-welded vine plants.

3.9.5. The Italian Nurseries

The Italian nurseries through the VCR cooperative has a commercial power beyond comparison with the French grapevine nurseries ('The main idea of VCR France consists of exploiting and reproducing the best clonal selections from the French INRA-ENTAV, of the public institutes in Italy, Germany, Spain, and from the breeders such as VCR with the aim of supplying growers with the widest possible plant range' (*free translation from French*) [52]). This company represents a unique case of a firm that became multinational in the industry, relying on its own research and under contract with the public research at the University de Udine [51]. This company is building market power through its technological innovation. Market power is established for sanitary and clonal selection. Market power provides potential for the dissemination of newly registered resistant Italian varieties.

3.9.6. The Proactive Grape Growers

The case of the Pugibet family [50] at Domaine de la Colombette is quite atypical in the organization of the dissemination of technical progress in France. In fact, by self-financing, this wine-growing operation anticipates the main sectoral changes: irrigation, minimal pruning, dealcoholization of wines, wines with low alcohol content, introduction of new resistant grape varieties, and even creation of new grape varieties in the long run.

This company values directly its own research and experimentation through the sale of the various categories of wines produced. This strategy is economically sound, despite the lack of subsidies and the administrative burden. It also acquires unique experience through an international environmental label. This precursor type is an essential factor of progress insofar as it serves as a stimulus for both researchers and 'well-established professionals'.

4. The New Resistant Grape Varieties Adapted to Climate Change

4.1. A Research Stream Competing against Other Strategies

The creation of new grape varieties adapted to climate change is a current research stream present in all research programs. However, this strategy provides only a long-term solution. In fact, programs such as LACCAVE (LACCAVE: Impacts et stratégies d'adaptation au changement climatique pour la viticulture et la production viticole en France) [65] have shown the many avenues of the mitigation of the effect of global warming, i.e. the authors proposed the implementation in the short run of a set of alternative solutions while waiting for the availability of those new grape varieties in the future.

At first, it concerns testing existing later varieties, which shortens the waiting time to around 20 years. To delay maturity, the use of more southern varieties is considered but with the same questioning of regional typicality. In Bordeaux, the experimental vineyard VitAdapt tested 52 grape varieties in order to define their physiology, their phenomenology, their maturity, and the quality of the wines, which makes it possible to assess their adaptation to climate change. This experimental project assesses in particular the Portuguese grape varieties such as Touriga Nacional and Tinto Cão (reds) and Greek such as Assyrtiko (white).

Likewise, clones for late-ripening are sought. These data are already known, but we also know that the clonal variability is lower than the genetic variability. It is a question of going back because historically, since the creation of the ANTAV in 1962, the National Technical Association for the Improvement of the Viticulture (in 1986, ANTAV became ENTAV, and in 2007, the ENTAV and ITV France merged. These two historical technical viticultural institutes became the new *Institut Français de la Vigne et du Vin* (IFV)), the clones were especially selected according to their productivity, their precocity, and the high potential of alcohol degree of the harvest. Therefore, today, it is a question of looking for the opposite characteristics. Likewise, the influence of rootstocks on varieties and clones constitutes a rapidly available mitigation modality.

Cultural practices can also be quickly mobilized by managing the leaf area, the distance from the ground, or later pruning. The structure of the latter can also be adapted to the target goals. The relocation of the vineyards remains one of the current questions, either toward the north or to higher altitudes, but here, the relocation of grapevine farms raises a real structural problem.

For drought, the use of irrigation is almost immediately accessible. In recent years, the Common Market Organization (CMO) for wine authorizes the subsidy of irrigation, which is significantly developing in southern regions. This policy orientation has been developed strongly in Italy and Spain since the 1990s with the purpose of saving water, increasing yields, and controlling quality [66].

4.2. Research in Progress to Take into Consideration the Diversity of Regional Situations

Varietal creation is no longer exclusively undertaken by the INRA in France. The IFV follows a similar pyramidal strategy as the INRA, i.e., the research of grapevines with polygenic resistance aiming for an adaptation to the *terroir* and climate as well as a typicality characteristic of a given wine region. The regions requesting such grape varieties define in collaboration with the IFV the release of a regional 'ideotype' [67].

Therefore, the logic of evaluation of new grape varieties changed. We move from the creation of a grape variety with the expected properties and then searching for where it could be established to the creation of a variety driven by the needs of the regional typicality. This strategy shortens the adoption times but in return multiplies the regional R&D programs and, therefore, enables a diversification of the technological paradigms.

4.3. From a Lab Model to an Accelerator for the Creation of Grapevines Adapted to Climate Change: The Microvines

Microvines open up new perspectives. In fact, this mutation observed in Australia has unique properties with faster recognition of the properties of the vines under study [68,69].

Only three R&D centers in the world have this vine available: in Australia, where it was discovered in 2002; in France at the INRAE Montpellier, and in Changins (Switzerland). This is a small variety of the grapevine Pinot Meunier, with uniqueness: the leaves are white, which is a characteristic that can be explained by the presence of a genetic mutation in the plant DNA. Beyond Montpellier and Changins, several European universities included the microvines in their programs (Udine, Valencia, Geisenheim, and Neustadt).

'The plant cycle, since the planting a seed until production of a new seed, takes only one year, compared to three to five years normally. And it only takes six months to produce a flower from a seed, a process that usually takes several years. On the other hand, the speed of growth from flower to fruit does not change: at the time of flowering, it takes one-hundred days before harvest' [68]. In addition, the management of this plant in a greenhouse makes it possible to simulate the conditions of adaptation to climate change.

The mutation of this microvine is natural, and a simple crossing with non-mutated vines is enough for the creation of new grape varieties. As Professor Torregrosa points out, this approach speeds up the assessment of new grape varieties in the face of climate change.

'Furthermore, we discuss and illustrate how the model can be used to identify quantitative trait loci (QTL) in fruit development and adaptive traits that could be useful when selecting genotypes in anticipation of the effects of global warming' [70] (We are grateful to Professor Laurent Torregrosa for allowing us to participate to the IBIP Seminar).

5. Conclusions and Future Perspectives

We would like to conclude by raising again our initial question: will the new grape varieties resistant to fungal diseases reduce the use of pesticides in viticulture and facilitate adaptation to global warming? The answer is: probably the day after tomorrow. Indeed, as in all the areas of innovation, and particularly in agriculture and even more so for perennial plants such as vines, time is a determining factor, ranging from the first crosses until significant dissemination of the vine plants.

If today, we only planted such resistant grape varieties, it would take twenty years to halve the volume of phytosanitary products currently used. The road faces many uncertainties. Table 2 shows the factors of progress and slowdown. It facilitates the comprehension of all the turbulence of such radical innovation.

Societal pressures toward the use of fewer pesticides and fears of global warming rehabilitated the activity of plant breeding. We have seen the diversity of technological paradigms and the innovation challenges for the different stakeholders of the wine chain. All the major producing countries implemented programs to meet those expectations and have even rehabilitated the initiators, which were rarely understood at their times, such as Alain Bouquet. Research tools made significant progress in fields such as molecular biology, molecular markers, and virology tests. The means implemented and their federation at the international level favors the acceleration of responses. The role of public authorities is to support these research programs and remove the obstacles to the evaluation and dissemination of these grape varieties. For a different perspective, Teissedre [71] highlights that for winemakers, the central question today is not about choosing a precise resistant grapevine but rather to choose a type of grapevine for a category of wines to be produced (PDO, PGI, wines without geographic indication).

Everything is embedded in a vineyard whose average renewal is low, reaching 2 percent at least in France, which is a little faster than in the countries located in Northern Europe. Since the arrival of phylloxera, plant material improved significantly. It is likely that the pressures emerging both from the society and from climate change will foster the adoption of new grape varieties as such varieties are created. It will justify a faster depreciation of plantings and the inclusion among the measures of the European agricultural policy.

We could also look back at the technological paradigms chosen. In particular the low use of molecular genetics techniques under pressure from ecological groups that have convinced most of the European society. These techniques could perhaps provide what the

current leaders of varietal wines dream of: the availability of the main traditional grape varieties in a version resistant to pests and diseases. However, here, it would lead us to a different story.

Table 2. The favorable and unfavorable factors to the diffusion of innovation and possible ways of improvement.

Favorable	Unfavorable	Improvement(s)
Strong desire for success on the side of research	Controversies about mono or polygenic	Continue to acquire knowledge on monogenic risks
Shortening of the lead times using molecular markers	Delay to register new varieties in the national catalog	Shortening procedures
Internationalization of research collaborations	Lack of an European catalog	Creation of an European catalog
Availability or near availability of technology supply (n^x of grape varieties)	Length of assessment procedures	Shortening evaluation deadlines, including by setting up a review procedure
Large number of new grape varieties proposed	Controversy over designations (i.e., names) of new grape varieties	Authorization of symbolic names/designations
Genetic diversity adapted to every country or region	Difficulty and length accessing to more qualitative categories (PDO-PGI)	Speed up access to those categories. Allow a gradual and limited introduction.
Very strong societal demand	Limitation related to plantings rights or new authorizations for plantings	Proposal of a 'quota of authorization plantings' for resistant grape varieties or adapted to climate change
Fear of poisoning liability lawsuits	Lack of subsidies for vineyard restructuring	Authorizing resistant grape varieties to benefit from subsidies
Pressure from French professionals	Lack of anticipation of grafting programs	
Interest for grape nurseries to develop this market	Weak communication toward future consumers	Communicating about the 'ecological' (i.e., green) grape varieties
The strong foothold of a multinational grape nursery: VCR	The notion and the reference to hybrid grapes and GMO	Explain and popularize classical genetic difference and GMO–Explain introgression
Establishment of the label PIWI	Weak budget. Except PDO-PGI	Developing the communication. Make it part of PGI.
Pioneers innovators	Legal and administrative burden	Support from institutions
Perspectives open through microvines	Lack of experience	Sustaining research programs

Author Contributions: Conceptualization, E.M., A.C. and S.Z.; formal analysis: E.M.; funding acquisition: E.M. and S.Z.; investigation, E.M., A.C. and S.Z.; methodology, E.M., A.C.; project administration, E.M.; A.C.; software, A.C.; writing-review and editing, E.M., A.C. All authors wrote, read and approved the final manuscript.

Funding: This research received no external funding.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Acknowledgments: The authors gratefully acknowledge the participation in the annual conferences of The Wine Links (Paris) and the seminar organized by Laurent Torregrosa (Montpellier).

Conflicts of Interest: The authors declare no conflict of interest.

References

1. Nelson, R.; Winter, S. *An Evolutionary Theory of Economic Change*; The Belknap Press of Harvard University Press: Cambridge, MA, USA, 1982; 437p.
2. Pendneault, K.; Provost, C. Fungus resistant grape varieties as a suitable alternative for organic wine production: Benefits, limits, and challenges. *Sci. Hortic.* **2016**, *208*, 58–77.
3. European Commission. *Study on Economic Value of EU Quality Schemes, Geographical Indications (GIs) and Traditional Specialties Guaranteed (TSGs), Final Report, Directorate-General for Agriculture and Rural Development*; Publications Office of the European Union: Luxembourg, 2019.
4. Commission of the European Communities. *Brussels, Report from the Commission to the European Parliament and the Council on the Use of Interspecific Vine Varieties Suitable for the Production of Quality Wines Produced in Specified Regions*; Bruxelles, 2003-12-30, COM(2003) 838 final; Commission of the European Communities: Brussels, Belgium, 2003; p. 9.
5. Durand, G. Théories évolutionnistes et management stratégique. In *Repenser la Stratégie: Fondements et Perspectives*; Laroche, H., Nioche, J.-P., Eds.; Vuibert: Paris, France, 1998; Chapter 6, pp. 135–164.
6. Hannan, M.T.; Freeman, J. *Organizational Ecology*; Harvard University Press: Cambridge, MA, USA, 1989.
7. Christensen, C.M.; McDonald, R.; Altman, E.J.; Palmer, J.E. Disruptive innovation: An Intellectual History and Directions for Future Research. *J. Manag. Stud.* **2018**, *55*, 1043–1078. [CrossRef]
8. Teece, D.J. Explicating dynamic capabilities: The nature and microfoundations (of sustainable) enterprise performance. *Strateg. Manag. J.* **2007**, *28*, 1319–1350. [CrossRef]
9. Teece, D.J.; Pisano, G. The Dynamic Capabilities of Firms: An Introduction. *Ind. Corp. Chang.* **1994**, *3*, 537–556. [CrossRef]
10. Teece, D.J.; Pisano, G.; Shuen, A. Dynamic Capabilities and Strategic Management. *Strateg. Manag. J.* **1997**, *18*, 509–533. [CrossRef]
11. Iansiti, M.; Khanna, T. Technological Evolution, System Architecture, and the Obsolescence of Firm Capabilities. *Ind. Corp. Chang.* **1995**, *4*, 333–361. [CrossRef]
12. Dosi, G.; Nelson, R.R. An introduction to evolutionary theories in economics. *J. Evol. Econ.* **1994**, *4*, 153–172. [CrossRef]
13. Dosi, G. Technological paradigms and technological trajectories: A suggested interpretation of the determinants and directions of technical change. *Res. Policy* **1982**, *11*, 147–162. [CrossRef]
14. Dosi, G. Sources, procedures and microeconomics effects of innovations. *J. Econ. Lit.* **1988**, *26*, 1126–1171.
15. Metcalfe, S. The economic foundations of technology policy: Equilibrium and evolutionary perspectives. In *Handbook of the Economics of Innovation and Technological Change*; Stoneman, P., Ed.; Blackwell: Oxford, UK; Cambridge, MA, USA, 1995; pp. 409–512.
16. Montaigne, E. Les techniques à membranes en œnologie: Une approche évolutionniste. In *Innovation, Changement Technique et Agro-Alimentaire, Economie et Sociologie Rurales: Actes et Communications 8*; INRA: Paris, France, 1991; pp. 127–140.
17. Witt, U. *The Evolving Economy: Essays on the Evolutionary Approach to Economics*; E. Elgar: Cheltenham, UK, 2003; 405p.
18. Montaigne, E. Enjeux et Stratégies Dans la Filière D'innovation du Matériel Végétal Viticole: Un Essai D'analyse Economique du Changement Technique. Montpellier I, Doctoral Dissertation (3rd cycle): Economie du développement Agro-alimentaire et Rural. Ph.D. Thesis, University of Montpellier, Montpellier, France, 1988; 642p.
19. Nicourt, C.; Girault, J.M. Le Coût Humain des Pesticides: Comment les Viticulteurs et les Techniciens Viticoles Français Font Face au Risque, Vertigo-la Revue Electronique en Sciences de L'environnement [Online], Volume 9 Numéro. 3 December 2009. Available online: http://vertigo.revues.org/9197 (accessed on 6 August 2021). [CrossRef]
20. Sud-Ouest. *Ecoliers Intoxiqués à Villeneuve (33) Après un Traitement des Vignes: Une Plainte Déposée*. 14 January 2016. Available online: http://www.sudouest.fr/2014/05/23/intoxication-a-l-ecole-de-villeneuve-33-la-sepanso-depose-plainte-1564352-3268.php (accessed on 6 August 2021).
21. Ministère de l'Agriculture. *Plan Ecophyto 2018 de Réduction des Usages de Pesticides 2008–2018*; Ministère de l'Agriculture: Paris, France, 2008; 21p.
22. Ministère de l'Agriculture. *CEPVITI Co-Conception de Systèmes Viticoles Economes en Produits Phytosanitaires, Guide Méthodologique*; Ministère de l'Agriculture: Paris, France, 2008; 28p.
23. Ramboll, Arcadia International. Study Supporting The Evaluation Of The Directive 2009/128/EC On The Sustainable Use Of Pesticides And Impact Assessment of Its Possible Revision; Validation Workshop, 4 May 2021; 26p. Available online: https://ec.europa.eu/food/plants/pesticides/sustainable-use-pesticides_en (accessed on 6 August 2021).
24. European Commission. Delivering the European Green Deal. Available online: https://ec.europa.eu/info/strategy/priorities-2019-2024/european-green-deal_en (accessed on 6 August 2021).
25. Van Leeuwen, C.; Destrac-Irvine, A.; Dubernet, M.; Duchêne, E.; Gowdy, M.; Marguerit, E.; Pieri, P.; Parker, A.; de Rességuier, L.; Ollat, N. An Update on the Impact of Climate Change in Viticulture and Potential Adaptations. *Agronomy* **2019**, *9*, 514. [CrossRef]
26. Ollat, N.; Touzard, J.-M. Adaptation à long terme au changement climatique pour la viticulture et l'oenologie: Un programme de recherche sur les vignobles français. *Ciëncia e Técnica Vitivinicola* **2013**, *28*, 288–294.
27. De la Fuente Lloreda, M. Use of hybrids in viticulture: A challenge for the OIV. *OENO One* **2018**, *52*, 231–234. [CrossRef]
28. Boursiquot, J.-M. Les Variétés Résistantes Issues D'hybridations Interspécifiques ne Peuvent Pas Etre Considérées Comme des Cépages de Vitis Vinifera. Réussir Vigne, Tribune. 15 June 2021. Available online: https://www.reussir.fr/vigne/jean-michel-boursiquot-les-varietes-resistantes-issues-dhybridations-interspecifiques-ne-peuvent (accessed on 6 August 2021).

29. Bouquet, A. 40 ans de progrès génétique et sélection de la vigne. Special Issue 'Quarante ans d'amélioration des plantes: Acquis et Perspectives'. *Le Sélectionneur Français* **2002**, *53*, 12.
30. Bartoli, P.h.; Boulet, D.; Lacombe, P.h.; Laporte, J.-P.; Lifran, R.; Montaigne, E. *L'économie Viticole Française*; INRA: Paris, France, 1987; 282p.
31. Bernaulte Laura, Bordeaux: Six Nouveaux Cépages Autorisés. Terre des Vins. 5 February 2021. Available online: https://www.terredevins.com/actualites/bordeaux-six-nouveaux-cepages-autorises (accessed on 6 August 2021).
32. Bécart, V. *Intérêt du Marselan, du Caladoc et du Couston en Côtes du Rhône*; Technical Paper; Syndicat des Côtes du Rhône, Institut Rhodanien: Orange, France, 2011; pp. 10–20. Available online: https://www.institut-rhodanien.com/download/1233 (accessed on 6 August 2021).
33. Abellan, A. Les vins AOC S'ouvrent aux Cépages Résistants au Mildiou et à L'oïdium. Vitisphère. 5 July 2021. Available online: https://www.vitisphere.com/actualite-94414-Les-vins-AOC-souvrent-aux-cepages-resistants-au-mildiou-et-a-loidium.htm (accessed on 6 August 2021).
34. OIV. *Resolution OIV-VITI 652-202. OIV Recommendations Concerning the Selection and Breeding of Grapevine Varieties for their Adaptation to the Effects of Climate Change*; OIV: Paris, France, 2021. Available online: https://www.oiv.int/fr/normes-et-documents-techniques/resolutions-de-l39oiv/resolutions-viticulture (accessed on 6 August 2021).
35. Salmon, J.M.; Ojeda, H.; Escudier, J.-L. Disease resistant grapevine varieties and quality: The case of Bouquet varieties. *OENO One* **2018**, *52*, 225–230. [CrossRef]
36. Schneider, C.; Prado, E.; Onimus, C.; Ley, L.; Forget, D.; Barbeau, G.; Audeguin, L.; Merdinoglu, D. *Vers une Viticulture à Faibles Intrants Phytosanitaires: ResDur, le Programme Inra de Création de Variétés de Vignes de Cuve Résistantes aux Maladies Cryptogamiques et de Bonne Qualité Œnologique*; Union Girondine des vins de Bordeaux: Bordeaux, France, 2014; pp. 62–68.
37. Tessier, R. *Règlement Technique D'examen des Variétés de Conservation en Vue de leur Inscription au Catalogue Officiel des Espèces et Variétés de Plantes Cultivées*; (Approved by Decree on the 16 December 2008, Published in the Journal Officiel, 6 January 2009); Service Note-DGAL/SDQPV/N2009-8013; Ministère de l'Agriculture et de la Pêche: Paris, France, 2009.
38. Ley, L. *Premiers Résultats de L'évaluation de Systèmes Viticoles Intégrant la Résistance Variétale*; Congress Euroviti 2018, 17 Jaétés et clones de Vigne: Bases Règlementaires du Catalogue et Modalités D'inscription; Agence Vinifera & al: Montpellier, France, 2011; p. 52.
39. Viret, O. Evolution de l'encépagement en Suisse. In *Des Plantes Sauvages aux Variétés Modernes*; Congrès CPC: Rütti, Switzerland, 20 November 2014; 48p.
40. Confédération Suisse, Département Fédéral de l'économie, de la Formation et de la Recherche DEFR. L'année Viticole 2014, Statistiques Viticoles; April 2015; 53p. Available online: http://www.blw.admin.ch/themen/00013/00084/00344/index.html?lang=fr (accessed on 6 August 2021).
41. Jörger, V. *Die Neuen Pilzwiderstandsfähigen Rotwein-Zuchtstämme*; Schweizer Zeitschrift für Obst-und Weinbau Nr. 5/02; Staatlichen Weinbauinstitut: Freiburg, Germany, 2014; pp. 90–94.
42. Wine, V. PIWI, Les Super Héros de la Vigne, L'express Styles. 26 February 2014. Available online: http://blogs.lexpress.fr/styles/miss-vicky-wine/2014/02/26/piwi-les-cepages-super-heros (accessed on 6 August 2021).
43. Rousseau, J. *Cépages Résistants aux Maladies Cryptogamiques, Mission D'étude en Suisse, Allemagne et France*; 7–9 June 2011, Synthèse; Cahier de l'Observatoire Viticole n 25; Agence Vinifera; Institut Coopératif du Vin; Conseil Général de l'Hérault: Montpellier, France, 2011; 57p.
44. Rousseau, J.; Chanfreau, S. *Les Cépages Résistants aux Maladies Cryptogamiques: Panorama Européen*; ICV: Lattes, France, 2013; 212p.
45. Vitis International Variety Catalogue VIVC: Dornfelder. Available online: https://www.vivc.de/index.php?r=passport%2Fview&id=3659 (accessed on 6 August 2021).
46. Deutsches Weininstitut. Deutscher Wein Statistik 2020/2021, Bodenheim, 2021, 38p. Available online: https://www.deutschewein.de/ (accessed on 6 August 2021).
47. Groeninger, R. Les Cépages Connus, Moins Connus ou en Voie de Disparition. Available online: http://lescepages.free.fr/regent.html (accessed on 6 August 2021).
48. Röckel, F.; Trapp, O.; Zyprian, E.; Hausmann, L.; Migliaro, D.; Vezzulli, S.; Töpfer, R.; Maul, E. A 'Regent' pedigree update: ancestors, offspring and their confirmed resistance loci. *Vitis* **2021**, *60*, 189–193. Available online: https://ojs.openagrar.de/index.php/VITIS/article/view/16088 (accessed on 2 November 2021).
49. Becker, N.J.; Zimmermann, H. Breeding of yield varieties resistant to downy mildew. In Proceedings of the Grapevine Genetics and Breeding. II. Symposium International sur l'Amélioration de la Vigne, Bordeaux, France, 14–18 June 1977; INRA: Paris, France, 1978; pp. 209–214. Available online: https://www.grapebreeders.com/Reprints/2nd%20Grape%20Breeding%201977_OCR.pdf (accessed on 6 August 2021)
50. Pugibet, F.; Pugibet, V. La Colombette, les Cépages Résistants. 2016. Available online: http://www.lacolombette.fr/colombette-2-60-Nos-particularites-Cepages-resistants.htm (accessed on 6 August 2021).
51. Tosi, L. Più resistenza nel vigneto Italia, Riparte in grande stile l'attività di miglioramento genetico della vite. *Terra Vita* **2014**, *43*, 8.
52. VCR France. Available online: http://www.vitisphere.com/salon-virtuel-materiel-equipement-5-1-1-Pepiniere-VCR-France.html (accessed on 6 August 2021).
53. Geoffroy, O. Nord-Est de l'Italie, Slovénie et Istrie, Study trip, 27th January to 3rd February 2013 IFV–Institut Français de la Vigne et du Vin, Lisle sur Tarn, 2013, 20p. Available online: https://www.vignevin-occitanie.com (accessed on 6 August 2021).

54. Abellan, A. Mildiou et Oïdium: 11 cépages résistants entrent au catalogue italien. *Vitisphère*, 16 September 2015.
55. Il Corriere Vinicolo. Viti Naturalmente Resistenti, 18 Varietà al Traguardo Registrazione. 2013. Available online: http://www.uiv.it/viti-naturalmente-resistenti-18-varieta-al-traguardo-registrazione/ (accessed on 6 August 2021).
56. Groeninger, R.B. Les Cépages Connus, Moins Connus ou en Voie de Disparition. Available online: http://lescepages.free.fr/bianca.html (accessed on 6 August 2021).
57. Reynolds, A. *Grapevine Breeding Programs for the Wine Industry*; Woodhead Publishing Series in Food Science, Technology and Nutrition; Elsevier: Waltham, MA, USA, 2015; 466p.
58. Trévoux, M. L'Inra Hésite à Diffuser les Variétés Résistantes d'Alain Bouquet. 23 November 2011. Available online: http://www.vitisphere.com/actualite-80227-LInra-hesite-a-diffuser-les-varietes-resistantes-dAlain-Bouquet.htm (accessed on 6 August 2021).
59. Trévoux, M. Vers une Reconnaissance Accélérée des Cépages Résistants Européens. Vitisphère. 19 January 2016. Available online: http://www.vitisphere.com/actualite-81776-Vers-une-reconnaissance-acceleree-des-cepages-resistants-europeens.htm (accessed on 6 August 2021).
60. Mayoux, L. *Catalogue français des variétés et clones de Vigne: Bases règlementaires du catalogue et modalités d'inscription*; Agence Vinifera & al: Montpellier, France, 2011; p. 52.
61. Mayoux, L. Introduction de nouveaux cépages au vignoble: Contexte réglementaire et perspectives d'évolution, FranceAgriMer/DRAAF LR, Secrétaire technique de la section Vigne du CTPS. In *L'Avenir du Plan Ecophyto Demain, Quelle Place pour les Cépages Résistants aux Maladies Cryptogamiques? Proceedings of the Conference Chambre d'Agriculture de l'Aude, Fermes, Ecophyto du Narbonnais, Gruissan, France, 17 October 2013*; Palais des Congrès: Gruissan, France, 2013; p. 10.
62. Zadmehran, S. Des Droits de Plantation de la Vigne aux Autorisations: Impact du Droit Foncier et des OCM-Vins sur la Dynamique Viticole Française. Ph.D. Thesis, University of Montpellier, Montpellier, France, 2020; 331p.
63. Villemin, V.; Andreff, W.; Montaigne, E. La marginalisation des minifundia: Le cas vitivinicole roumain face aux politiques publiques. *Econ. Rural.* **2011**, *325–326*, 129–144. [CrossRef]
64. Goma Fortin, N. *Cépages Résistants aux Maladies Cryptogamiques*; Chambre d'agriculture de l'Hérault: Montpellier, France, 2014; p. 12.
65. INRA. Long Term Adaptation to Climate Change in Viticulture and Enology-LACCAVE, Métaprogramme ACCAF Rapport Final: Résultats Pour la Période 2012–2016, French ed. 2016, p. 62. Available online: https://www6.inra.fr/laccave/ (accessed on 6 August 2021).
66. Galletto, L.; Barisan, L.; Boatto, V.; Costantini, E.A.C.; Lorenzetti, R.; Pomarici, E.; Vecchio, R. More Crop for Drop–Climate Change and Wine: An Economic Evaluation of a New Drought-Resistant Rootstock. *Recent Pat. Food Nutr. Agric.* **2014**, *6*, 100–112. [CrossRef] [PubMed]
67. Audeguin, L.; Sereno, C.; Yobrégat, O. Variétés de vigne de demain: Évolutions attendues, attentes professionnelles et sociétales, challenges. In Proceedings of the 38th World Congress of Vine and Wine, Mainz, Germany, 5–10 July 2015. [CrossRef]
68. Schupbach, J. La Microvigne, une Vigne Modèle pour Elaborer les Vins du Futur. Le Temps. 2016. Available online: https://www.letemps.ch/sciences/microvigne-une-vigne-modele-elaborer-vins-futur (accessed on 6 August 2021).
69. Pellegrino, A.; Romieu, C.; Rienth, M.; Torregrosa, L. The microvine, a versatile plant model to boost grapevine studies in physiology and genetics. In *Advances in Grape and Wine Biotechnologies*; Morata, A., Ed.; IntechOpen: London, UK, 2019.
70. Torregrosa, L.; Rienth, M.; Romieu, C.; Pellegrino, A. The microvine, a model for studies in grapevine physiology and genetics. *OENO One* **2019**, *53*, 373–391. [CrossRef]
71. Teissedre, P.-L. Composition of grape and wine from resistant vine varieties. *OENO One* **2018**, *52*, 211–217. [CrossRef]