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Chapter

Adaptability of Different International Grape Varieties in Diverse Terroirs: Impact on Grape and Wine Composition

Tatiane Otto, Renato Botelho, Luiz Biasi, Uroš Miljić, Ana C. Correia and António M. Jordão

Abstract

In the last two decades, several international grape varieties from different traditional wine countries such as, France, Portugal, Italy, and Spain have been introduced in several world wine regions, increasing their representation in the world. The introduction of grape varieties in emerging regions with diverse environmental conditions from their natural origin introduces challenges on the adaptability of these varieties in new specific “terroirs,” not only in terms of their productivity but also related with the grape and wine characteristics. In addition, it is also important to compare their characteristics with native grape varieties grown in the local regions. On the other hand, climate change has also promoted greater mobility of grapes to new regions, increasing the dispersion of various grape varieties in areas where viticulture was, until now, severely limited. Thus, considering the importance of the dispersion of several grape varieties in regions out of the original provenance, the purpose of this chapter is to present a review of the most recently published data about the adaptation of several grape varieties in different environments and the impact on their qualitative characteristics (including in wines produced). The comparative analysis with some of the native varieties existing in these environments, when applicable, will also be analyzed.

Keywords: adaptability, chemical composition, grape varieties, wine quality, sensory profile, terroir

1. Introduction

The Vitis genus (80 species identified) is composed of two sub-genera: Muscadinia and Euvitis [1]. The Muscadinia sub-genus comprises three species, including M. rotundifolia. This sub-genus grown in the south-east of North America is remarkably resistant to the main cryptogamic diseases to which most Vitis vinifera varieties are prone [2, 3]. However, most cultivated grapevines belong to the Euvitis sub-genus. These sub-genera fall under three groups: the American (made up of more than
20 species), the East Asia (comprises about 55 species), and the Eurasian group (composed of one single species, *V. vinifera* L.). For *V. vinifera* specie, there are two sub-species: *sylvestris*, which corresponds to the wild form of the vine, and *vinifera*, referring to the cultivated form [4].

The *Vitis* international variety catalog identifies 21,045 names of varieties, which includes 12,250 for *V. vinifera*. However, this last number includes a considerable number of synonyms and homonyms [5]. Nevertheless, according to Lacombe [6], the number of vine varieties for the *V. vinifera* species in the world is estimated at 6000. The high number of varieties is a consequence of the preservation and transport of vine seeds by farmers, which was a common practice in the past. However, also the interspecific hybridization of *Vitis*, which occurred during nineteenth century until the mid of twentieth century, also contributed to the diversity of genetic material. In that case, the phylloxera crisis had an important role in the creation of high diversity of plant material. Lastly, the natural genetic mutations, which are common in grapevines, also contribute for this diversity.

According to OIV data, grape vineyards (which corresponding to the total surface area planted for all proposes—wine and juices, table grapes, and raisins) covered more than 7.3 million hectares worldwide [7]. Lecat et al. [8] reported that in 2015, the estimation net worth of the wine industry was more than 258 billion euros. However, in 2020, the world wine consumption estimated at 234 mL and had a decrease of 3% compared with 2019. This decrease could be a consequence of the first year of the COVID-19 sanitary crisis, which induces an asymmetrical aggregate consumption behavior in different countries in the world [9]. Nevertheless, for a global point of view in the last decade, wine sector has undergone considerable changes. One of these changes is related with the grubbing-up of vineyards and restructuring activities. Indeed, some traditionally high-production varieties no longer correspond to the tastes of consumers or the market and have seen a significant decline in their surface area. In addition, as vineyard productivity is strongly related to climate, the tendency observed in last decades for significant changes in climatic conditions, namely for atmospheric temperatures, has been shown to affect grape yield and composition and wine sensory profile. Consequently, the use of different grape varieties of local origin and/or from other wine regions could be a strategy to be followed by winegrowers from different geographical locations [10–12].

In the last 20 years, several authors reported an occurrence of varietal concentration in the world vineyards. According to Anderson and Aryal [13], for instance, Cabernet Sauvignon and Merlot grape varieties have more than doubled their vineyard area. As a result of this situation, Cabernet Sauvignon has been widely studied mostly because its worldwide distribution [14–18]. In addition, numerous studies have shown that grape and wine composition obtained from the different vine varieties depends on several factors that change not only according to the intrinsic potential of each grape variety [17, 19] but also according to the climatic factors, such as sunlight exposition, solar radiation, and temperature [12, 20], soil [21], agricultural practices [22], and also the level of grape ripeness [23]. Thus, winegrowers have traditionally selected and maintained the different grape varieties introduced in the different wine regions, especially the cultivars from other countries and terroirs that best match their specific climates and soil conditions. In addition, recently the wine sector has focused on research and experimental activities about the adaptive capacity of the most economically important grape varieties to climate change in different wine regions. In this perspective, the adaptability of several grape varieties to new regions and climates, as well as, in some cases, the
comparative assessment with the native grape varieties from these regions, has allowed us to obtain new data [17–19, 24, 25].

Thus, this chapter focuses on the latest scientific knowledge about the adaptation of several grape varieties in different environments and the impact on grape and wine characteristics. It also approaches diverse comparative data between the international grape varieties introduced in several wine regions and the local native varieties.

2. World distribution of main international grape varieties

According to the OIV database, out of the 10,000 vine varieties known in the world, there are 13 that represent more than one-third of the world vine area [26]. In addition, 33 vine varieties represent 50% of the total vine area. Some varieties are mainly cultivated in a restricted number of countries, such as the Kyoho grape, mainly cultivated in Asia (Japan, China, and South Korea). In an opposite situation, there are other varieties that grow in many countries and usually are called as “international” varieties. One of most important demonstrative examples is the Cabernet Sauvignon grape.

Among the main varieties most cultivated around the world, it is possible to find several countries that are specialized in wine production, such as France, Spain, Italy, Australia, and Argentina, while others are more focused on table and dried grapes production, such as Turkey, Iran, India, or China. However, in the last years, China has shown a great increase in both productions, either wine or table grapes.

Table 1 shows the distribution of the main grape varieties cultivated in the different world geographical areas. As shown in this table, Kyoho grape occupies the largest area of grape vines in the world, although its geographical distribution is restricted to the Asian continent especially in China, which represents more than 90% of the vines area. This table grape variety has been the most produced grape in Japan since 1994, and in South Korea, it accounts for 14.5% of the country’s vineyards [27]. For wine grapes, the Cabernet Sauvignon is the most cultivated variety in the world, being distributed in almost all wine-producing countries. From Bordeaux region (France) and derived from a crossing between Cabernet Franc and Sauvignon Blanc variety, Cabernet Sauvignon is the second most-planted vine variety [28]. Today, its vines are widely distributed across the world, covering 5% of the world’s vineyards (representing 341,000 ha). It is grown in a great number of countries, such as China, France, Chile, the United States, Australia, Spain, Italy, and South Africa. This grapevine adapts to a wide range of environments with a broad phenotypic plasticity (including differential wine sensory attributes). Then, this variety has a high capacity of acclimatization to the different environments and adaptation to climate change [29–31].

For the remaining varieties, such as the Sultanina, Merlot, Syrah, and Tempranillo, it is clear a great geographical distribution being present in several of the major grape wine producing countries. Merlot and Syrah varieties are both from France, the first from the Bordeaux region and the second from the Rhône Valley region. Today, Merlot is present in 37 countries and covered 266,000 ha or 3% of the total world area under vines, while Syrah covered 190,000 ha, and it was grown in 31 countries. Specifically, Tempranillo wine grape is not widely grown outside of Spain, but it may be present in 17 countries. However, 88% of its cultivated area is in Spain.

Although the distribution of the main varieties has spread by the largest grape producers and is very dependent on international varieties, it is important to point out that some countries have obvious dominant varieties in their vineyards, such as Spain,
which has two main varieties, Airen and Tempranillo, that cover more than 40% of the vines area. In China, 44% of the vines are from the Kyoho grape [26]. In addition, there are a few wine countries, such as Italy, Portugal, and Romania that show a quite diverse varietal distribution, with main varieties not exceeding 9% of the area under vine. These first two countries show an important number of different varieties, especially native cultivars covering 75% of their area of grapevines.

Figure 1 shows examples for a few wine country producers from different geographical origins about the distribution of the main varieties according to the data obtained from OIV [26]. By analyzing the data presented in Figure 1, it is possible

<table>
<thead>
<tr>
<th>Grape variety</th>
<th>Skin color</th>
<th>Production destination</th>
<th>Area (ha)</th>
<th>Country origin</th>
<th>Main geographical distribution</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kyoho</td>
<td>Black</td>
<td>Table</td>
<td>365,000</td>
<td>Japan</td>
<td>Japan, China, and South Korea</td>
</tr>
<tr>
<td>Cabernet Sauvignon</td>
<td>Black</td>
<td>Wine</td>
<td>341,000</td>
<td>France</td>
<td>China, France, Chile, United States, Australia, Spain, Italy, and South Africa</td>
</tr>
<tr>
<td>Sultanina (syn. Thompson Seedless)</td>
<td>White</td>
<td>Table, drying and wine</td>
<td>273,000</td>
<td>Afghanistan</td>
<td>Turkey, Iran, Iraq, Afghanistan, Pakistan, and Central Asia</td>
</tr>
<tr>
<td>Merlot</td>
<td>Black</td>
<td>Wine</td>
<td>266,000</td>
<td>France</td>
<td>France, Chile, United States, Italy, and Australia</td>
</tr>
<tr>
<td>Tempranillo</td>
<td>Black</td>
<td>Wine</td>
<td>231,000</td>
<td>Spain</td>
<td>Spain, Portugal, and Australia</td>
</tr>
<tr>
<td>Airén</td>
<td>White</td>
<td>Wine and brandy</td>
<td>218,000</td>
<td>Spain</td>
<td>Spain</td>
</tr>
<tr>
<td>Syrah</td>
<td>Black</td>
<td>Wine</td>
<td>190,000</td>
<td>France</td>
<td>France, Australia, Argentina, South Africa, United States and Chile</td>
</tr>
<tr>
<td>Red Globe</td>
<td>Black</td>
<td>Table</td>
<td>159,000</td>
<td>Italy</td>
<td>China, United States, Spain, Portugal, Italy, and Chile</td>
</tr>
<tr>
<td>Garnacha Tinta/ Grenache Noir</td>
<td>Black</td>
<td>Wine</td>
<td>163,000</td>
<td>Spain</td>
<td>Spain and France</td>
</tr>
<tr>
<td>Sauvignon Blanc</td>
<td>White</td>
<td>Wine</td>
<td>123,000</td>
<td>France</td>
<td>France, Spain, Italy, South Africa, United States, and New Zealand</td>
</tr>
<tr>
<td>Pinot Noir/ Blauer Burgunder</td>
<td>Black</td>
<td>Wine</td>
<td>112,000</td>
<td>France</td>
<td>France, Germany, Italy, United States, Australia, Argentina, and South Africa</td>
</tr>
<tr>
<td>Trebbiano Toscano/Ugni Blanc</td>
<td>White</td>
<td>Wine, brandy</td>
<td>111,000</td>
<td>Italy</td>
<td>France, Italy, Portugal, Argentina, and Australia</td>
</tr>
</tbody>
</table>

Table 1. Distribution of the main grape varieties cultivated in the different world geographical areas. Data obtained from OIV [26].
to observe that for Spain, one of the biggest wine producers, native varieties are in majority. Airén and Tempranillo occupied around 43% of the vine area. Varieties of foreign origin, namely French, occupy secondary positions, with Garnacha Tinta, Alicante Bouschet, Cabernet Sauvignon, and Syrah being the most representative these varieties.

An opposite tendency is observed for the main varieties cultivated in France. Thus, except for Ugni Blanc, a variety originally from Italy (Tuscany) where it is grown under the name Trebbiano Toscano, all main varieties are from French origin. In that case, Merlot, Grenache Noir, and Syrah are the main varieties, while other varieties very widespread all over the world, such as Chardonnay, Cabernet Sauvignon, and Pinot Noir occupied values between 4 and 6% of the vine area.

An interesting distribution of the main grape varieties is observed in Portugal, a country considered to be one of the countries with the highest varietal distribution,
with main varieties not exceeding 9% of the area under vine and at the same time, all main native grape varieties represent around 50% of the vine area. Syrah is the most representative no native variety, and it represents only 3% of vine area. Considering some of the highest wine-producing countries in the “new world,” such as Argentina and Australia, the varieties have a foreign origin, namely from France (the majority), but also from Spain, as is the case of the variety Cereza. In Argentina, Malbec and Cereza represent 18 and 13% of vine area, respectively, while for Australia, Syrah (27%), Cabernet Sauvignon (17%), and Chardonnay (14%) are the most representative varieties. Finally, in United Sates, similar tendency is observed, where Chardonnay and Cabernet Sauvignon are the main representative varieties for wine production.

3. Impact of different terroirs on grape composition

According to several authors, it is expected that the combination of plant material (genotype), fungi and bacteria population (microbiome), soil and climate conditions, and all factors related with vineyard management and winemaking affect the quality of grapes and consequently the wines produced. Thus, interactions between all of these factors are usually mentioned as the “terroir” and are finally expressed in the grape composition and consequently in wine characteristics [31–33]. According to Magalhães [34], on the basis of these interactions, the concept of “terroir” has been extensively adopted for the majority of the authors. In fact, all wine regions are characterized by their natural environment conditions, usually related with climate and soil properties, but also depend on human factor. In 2010, the Organization of Vine and Wine issued the resolution VITI 333/2010 with the concept of “terroir” as “an area in which collective knowledge of the interactions between the identifiable physical and biological environment and applied viticultural and enological practices develops, providing distinctive characteristics for the products originating from this area. Terroir includes specific soil, topography, climate, landscape characteristics and biodiversity features.” According to Carbonneau [35], the most important key factor on grape varieties adaptability is the climatic characteristics of each wine region. Instead, Van Leeuwen et al. [36] consider that “terroir” induces all development of grapevine, berry composition and at same time is a key factor that determines the final wine quality, including their typicity and the global characteristics of each wine region.

Thus, it is possible to consider that the adaptability of the different grape varieties, particularly when grown outside their original region is related with a set of factors, namely, atmospheric conditions (temperature, precipitation, humidity, and solar radiation), soil composition and water availability for the plant, potential climate change, pest and diseases, diverse viticultural practices, and varietal/clonal and rootstock selection [37–42]. In the past years, the adaptability of grapevine to different conditions is also related with the development of the modern grapevine breeding, producing numerous hybrid varieties with different characteristics such as cold/hot-resistant, rapid ripening and with resistance to several diseases [43]. These hybrids have made it possible to cultivate vines even in regions where environmental conditions are still a very limiting factor for the development of the vines, as is the case in Nordic countries [44]. Today, also in non-European countries, the use of hybrids is common. For example, in Brazil, several hybrid varieties, such as Moscato Embrapa, Niagara, Villenave, Goethe and Manzoni Bianco and Vitis labrusca vines, are usually used with great success for wine production [45]. Also, Cabernet Cortis,
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Cabernet Carbon, Bronner, and Regent are other American hybrid vines recently tested in several experimental works in this South American country [46]. However, it is important to note that the preservation of the existent biodiversity related with autochthonous grape varieties is essential to maintain many of the specific and differentiating characteristics of the winegrowing regions. In addition, these varieties could play an important role in the response to climate change and to be used in new opportunities for adaptation to other regions [24, 47].

Cabernet Sauvignon, Malbec, Merlot, Tempranillo, Cabernet Franc, Syrah, and Malbec are several examples of varieties well adapted to different production conditions, namely to very dry and warm climates. Some of them are very cultivated in several countries of southern Europe [48]. In general, these non-native varieties show characteristics associated with own productivity and composition not only related to their own genetics but also develop characteristics that result from their adaptation to the different terroirs where they are implanted.

In Portugal, in the last 20 years, several French grape varieties have been introduced in several wine regions, particularly in the south of the country. For example, Cabernet Sauvignon has been cultivated in different regions, such as Lisbon and Alentejo wine regions with different results and specific characteristics. Thus, Ó-Marques et al. [15] reported no significant differences in grape berry composition, especially related with different general physicochemical characteristics (titratable acidity, pH, estimated alcoholic degree, and berry weight) between Cabernet Sauvignon and Tinta Roriz grape varieties, while other authors found significant differences between several French and Portuguese native grape varieties in other wine regions [49]. In that case, French Cabernet Sauvignon, Merlot, Pinot Noir, and Syrah had higher titratable acidity than two Portuguese grape varieties, Touriga Nacional and Tinta Roriz, in samples collected in a vineyard located in “Douro” region (North of Portugal). In this study also, taking into consideration the phenolic composition, all the French grape varieties assessed had higher total phenols compared with the native grape varieties. For example, Alicante Bouschet (variety from French origin but widely cultivated in the south of Portugal, being officially recognized as a native variety) had the highest values for total phenols and flavonoid compounds (global average value from 0.636 to 0.894 and from 0.584 to 0.834 mg/g of berry, respectively, for total phenols and flavonoid compounds). However, for total anthocyanins, Portuguese native grape varieties (Tinta Roriz and Touriga Nacional) had highest values [49].

Cosme et al. [50] studied the tannin profiles of different *Vitis vinifera* L. red grapes grown in Lisbon region having Portuguese (Touriga Nacional, Trincadeira and Castelão) and French (Syrah and Cabernet Sauvignon) origin. These authors reported that the tannin profile of grape skin was different between cultivars. Thus, the Portuguese Castelão variety showed the lowest mean degree of polymerization (mDP) of proanthocyanidins while Cabernet Sauvignon had the highest mDP. In addition, this French variety had the lowest concentration of total proanthocyanidins in the skins, but this distribution was mainly at the higher mDP (mDP values >30).

It is well known that high temperatures could determine the grape maturation process, accelerating grape berry maturation and at the same time inducing the production of grape berries with higher soluble solids content [51]. In addition, hot temperatures during the day and cold nights induce lower pH values of the grape musts and decrease tartaric and malic acid degradation when compared with regions with hot days and nights. Several authors reported that Syrah, Cabernet Sauvignon, and Alicante Bouschet are grape varieties with minor thermal demands to achieve a normal maturation compared with some native grape varieties, especially taking into
consideration the sugars content and titratable acidity in several Portuguese regions characterized by high temperatures [14, 49]. Gordillo et al. [52] reported for warm climatic conditions, which occur in South of Spain (Condado de Huelva D.O.), a high resistance of Syrah variety to these high temperature conditions that occur during maturation.

According to Costa et al. [19], the genetic factor has an important role on phenolic content between the grape varieties and not only the “terroir.” According to these authors, the major individual anthocyanin group (monoglucosides) content for Cabernet Sauvignon is independent of the wine region where this variety is produced. Similar tendency was also described by other authors [16, 53], where the biosynthesis of this anthocyanin group is mostly ruled by genetic factors than by climatic conditions. According to Flamini et al. [54] and Sikuten et al. [55], the composition of individual anthocyanins is under genetic control, while agronomic and environmental factors have a greater impact on their total content. In addition, under conditions characterized by dry periods and water deficit, several authors have shown that Cabernet Sauvignon may present lower alcohol level and phenolic content and at the same time higher values of total acidity [56, 57]. Nevertheless, recently other researchers reported under a semi-arid climate condition of Israel that Cabernet Sauvignon vines submitted to late irrigation (in last stages of grape maturation) produced grapes with higher color intensities and phenolic content [25]. For different vines from *V. vinifera* and several hybrid cultivars cultivated in the Finger lakes area of New York State (United States), Yang et al. [58] reported that Cabernet Franc and Pinot Noir had the highest total phenolic content (values varied from 396.8 to 424.6 mg/100 g) compared with remaining hybrid varieties studied.

In Spain, most vines cultivated are native varieties, occupying more than 50% of the vineyard area. Monagas et al. [59] studied the flavan-3-ol composition of grape seeds and skins from Cabernet Sauvignon and two Spanish grape varieties, Graciano and Tempranillo, cultivated in Navarra region (North of Spain). The higher concentration of flavan-3-ols was observed in Graciano and Cabernet Sauvignon while the lowest values were quantified for Tempranillo variety. This result demonstrates a tendency for an adequate adaptability of the Cabernet Sauvignon under the conditions of this Spanish region, namely in terms of the flavan-3-ols biosynthesis. Several aroma compounds are very important for wines quality, especially for white wines. In this case, terpenes are the source of the fruity and floral aromas found in white wines produced from different grape varieties, such as Riesling, Albariño, Muscat, and Gewürztraminer. García et al. [60] studied the changes in volatile compounds of the most representative white grape varieties cultivated in central La Mancha region of Spain (Macabeo, Airén, and Chardonnay). According to these authors, Chardonnay, a French grape variety that is increasingly being grown in this Spanish wine region, showed higher total acidity compared with the native grape varieties for the same degree of maturity. In addition, several important volatile compounds were quantified in significant values for this French variety. Thus, grape must from Chardonnay had the highest values of 1-2-hexenol, hexanol, benzaldehyde, phenyl-acetaldehyde, and benzyl alcohol compared with Macabeo and Airén varieties. These results confirm the good adaptability of this white grape variety to the dry conditions of La Mancha Spanish wine region. Also, in other European regions as in the eastern European countries, several international grape varieties have been introduced. These varieties have been cultivated in parallel with the native grape varieties of these countries. Thus, for example, in Serbia, the most represented native grape varieties are Grašac, Prokupac, Tamjanika, Smederevka, Kadarka, and Bagrina. Apart from
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this native varieties, international cultivars, such as Merlot, Cabernet Sauvignon, Chardonnay, and Riesling, cover also larger vineyards areas (around 570, 560, 510, and 440 ha, respectively). In the last 10 years, several authors reported comparative data on the chemical composition between international and autochthonous varieties grown in Serbia [61–64].

The vineyards with international varieties have a heterogeneous population and enologists emphasized the importance of clonal selection for getting the clones with best properties for specific terroirs. This is especially important for the varieties with high genetic diversity [65]. The characteristics of a clone mostly depend on the environmental conditions. The production of certified planting material of selected clones is required at the end of process. Vujović et al. [66] studied the evaluation of agrobiological and technological characteristics of three Merlot and Cabernet Franc clones during 5 years (2009–2013) in Grocka wine region (Central Serbia). They observed that individual grape berries from different clones, but also on the same bunch, do not ripe uniformly and the values of the monitored parameters vary significantly. Thus, at the harvest, Merlot (clone 025) and Cabernet Franc (clone 010) had the highest values of total phenols content (7.32 and 10.9 g GAE/Kg frozen weight, respectively) and total anthocyanin content (386 and 1668 mg/Kg malvidin-3-glucoside equivalents frozen weight, respectively). Concerning the individual polyphenols, the following compounds were the most abundant in the both international varieties studied: gallic acid, (+)-catechin, (−)-epicatechin, gallocatechin gallate, (+)-catechin gallate, and rutin [62]. Mitić et al. [61] compared total phenolic content between international grape varieties (Cabernet Sauvignon and Merlot) and two native Serbian varieties (Prokupac and Vranac). The results obtained showed a tendency for the two Serbian native varieties studied and have presented lower values of total phenols (between 156 and 158 mg of GAE/100 g of grape) compared with the two international grape varieties (173 and 169 mg of GAE/100 g of grape, respectively for Cabernet Sauvignon and Merlot). Similar trend, i.e., lower amounts of total flavonoids and total anthocyanins, was obtained for Prokupac and Vranac varieties. In fact, Vranac is considered an autochthonous red variety in several Balkans countries, namely from Republic of Macedonia, Serbia, and Montenegro. According to these authors, Vranac grapes also contained similar amount of (+)-catechin as Merlot and (−)-epicatechin as Cabernet Sauvignon. However, the contents of these flavan-3-ols in Prokupac grapes were significantly lower. Opposite tendency was reported by Pantelić et al. [63] where Prokupac variety had the highest content of total phenols in seeds (around 100 mg GAE/g) and skins (around 12 mg GAE/g) compared with several international varieties (Cabernet Sauvignon, Merlot, Cabernet Franc, Syrah, Sangiovese, Pinot Noir, Riesling, Chardonnay, Sauvignon Blanc, and Pinot Gris) cultivated in Central Serbia. These authors also reported for the first time the presence of malvidin 3,5-O-dihexoside in the skins of Merlot, Cabernet Franc, Syrah, Sangiovese, Pinot Noir, and Prokupac grapes, explaining, however, that this compound is not characteristic for V. vinifera L. varieties.

Table 2 summarizes several results obtained for general physiochemical and phenolic parameters of several international and native red grape varieties cultivated under different geographical locations.

Also in South America countries, namely in Argentina, Chile, and Brazil, the great majority of vine varieties used are international varieties, having French and Italian origin. In Brazil, most varieties planted are Cabernet Sauvignon, Merlot, Syrah, and Pinot Noir, all of them from French origin, and Barbera, Ancellotta, Trebbiano, Riesling Itálico and Moscato Giallo, all of them from Italian origin. Thus, in recent
<table>
<thead>
<tr>
<th>Parameters</th>
<th>Country/geographical location/reference/grape variety</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Portugal/Douro region</td>
</tr>
<tr>
<td>Estimated alcohol degree (% v/v)</td>
<td>14.0</td>
</tr>
<tr>
<td>Titratable acidity (g/l tartaric acid)</td>
<td>6.7</td>
</tr>
<tr>
<td>pH</td>
<td>3.25</td>
</tr>
<tr>
<td>Total phenols (mg/g berry)</td>
<td>0.474</td>
</tr>
<tr>
<td>Total anthocyanins (mg/g berry)</td>
<td>0.517</td>
</tr>
<tr>
<td>Total flavan-3-ols (mg/g skins)</td>
<td>—</td>
</tr>
<tr>
<td>(+)-catechin (mg/g skins)</td>
<td>—</td>
</tr>
<tr>
<td>(−)-epicatechin (mg/g skins)</td>
<td>—</td>
</tr>
</tbody>
</table>

1French variety.  
2Portuguese variety.  
3Spanish variety.  
4Serbian variety.  
5Average values from two vintages (2010 and 2011).  
6Average values from vintage 2000.  
7Average values of four vintages (2014 and 2016) under a tropical semi-arid region.
Table 2.
General physiochemical and phenolic composition of several international and native red grape varieties cultivated under different geographical locations.
years, several studies have been published that present results on the adaptability of the various varieties in the different regions with conditions for grape wine production. In these regions, the minimum temperature is not sufficiently low to induce natural vegetative repose in the vines. Oliveira et al. [71] reported chemical characteristics of grapes Syrah grown in a Brazilian tropical semiarid region (Pernambuco State) during four growing seasons (two calendar years, 2016 and 2017). According to these authors, in the semiarid region considered, the interaction between the Syrah grape and the climatic conditions in each harvest season (combined also with the different rootstocks) determines the composition of the grapes. For example, grapes harvested in July of the first harvest season, where the temperatures are lower, showed higher total acidity, total monomeric anthocyanins, and total tannins in seeds, than grapes harvested in December from the second harvest season, characterized warmer temperatures. Also, Stefanello et al. [72] studied the potential of Alicante Bouschet variety in the Campanha Gaúcha region, southern Brazil, between 2013 and 2017. At the same time, yield and chemical composition of the grape must subjected to nitrogen application without irrigation, followed by irrigation and via fertigation were evaluated. These authors concluded a good adaptation of this French variety to environmental conditions of Southern Brazil and at same time the grapevines grown in control soil without Nitrogen fertilization had the highest values of total soluble solids in the must in all the crop seasons considered. In 2011, Borghezan et al. [73] also reported that Cabernet Sauvignon, Merlot, and Sauvignon Blanc produced grapes with high quality, being suitable for cultivation in São Joaquim, Santa Catarina State (Brazil). Chile and Argentine show in general red and white grape varieties from different origins well adapted to the different terroirs in the diverse wine regions. Among Chilean varieties, Carignan Noir, a variety of Spanish origin (Aragón region), has had a major resurgence due to its rediscovered wine quality potential. Martinez-Gil et al. [74] reported results for this red grape variety by the characterization of phenolic composition of grapes grown in different locations from the Maule Valley. The data obtained show high enological and viticultural attributes for grape growers of this cultivar inducing differentiable attributes in terms of grape composition. For Argentina, Malbec is the most important variety. This is a red grape variety originated from France; however, Argentina has the highest acreage of vineyards of this variety (representing around 77% of the world production) being emblematic for Argentina’s winemaking industry [75]. Several, authors describe that this variety requires an intermediate to warm climate, low rainfall, and with solar potential. These conditions are found in several Argentinian wine regions producing Malbec grapes and wines with a high quality [76, 77].

Finally, it is important to considerate the adaptability of different international grapes varieties in one of the biggest and dynamic wine country as is the case of China. This country has had a great success in the grape and wine production with an extraordinary development. Most grapes are from red varieties (around 80%), while the white varieties represent only 20% [78]. For red varieties, Cabernet Sauvignon, Merlot, and Cabernet Gernischt have a great adaptability to the different Chinese wine regions with diverse climatic and agronomic conditions. The white grapes, Italian Riesling, Chardonnay, and Riesling, are the most cultivated varieties [79, 80]. In last years, several studies were carried out to analyze the adaptability of the different *V. vinifera* varieties in the different Chinese wine regions under diverse climatic and soil conditions combined with several agronomic practices. The results show a good adaptability for most of the cultivars maintaining all its specific potentialities but affected by the environmental conditions [81, 82].
4. Influence of different environmental conditions on wine composition

Apart from grape composition of the different international varieties cultivated under different environmental conditions, several studies have been carried out on the composition of the wines produced and their sensory profile. However, although international varieties are in general well adapted to specific environmental and production conditions, the wines from native varieties are shown to possess at least equal potential concerning the quality. Žurga et al. [83] reported comparative data from Croatian wines made from native (Plavac Mali and Teran) and non-native grape varieties (Merlot and Cabernet Sauvignon), both cultivated in Croatian coastal regions. According to these authors, wine produced from Plavac native grape variety had the highest total phenolic and (+)-catechin content, while Merlot and Cabernet Sauvignon wines had higher flavonol content. According to these authors, there are distinct genetic potentials between Croatian autochthonous and no autochthonous (specifically for Merlot and Cabernet Sauvignon) varieties. Additionally, several authors reported data from Merlot and Cabernet Sauvignon wines elaborated in Serbian Fruška gora wine region (Northern Serbia). Similar total phenols (ranged between 1460 and 1560 mg GAE/l) and total anthocyanins (ranged between 329 and 319 mg malvidin-3-glucoside equivalents/l) content were found between these wines [84–87]. Also, Vujović et al. [66] studied the impact of three Merlot clones uses on wine quality under Central Serbia wine region conditions (Grocka wine region). These authors found total phenols values being between 1100 and 1500 mg GAE/l. Sredojević [87] compared young wines produced from Cabernet Sauvignon variety and Serbian native varieties (Prokupac, Crna Tamjanika, Plovdivina, Smederevka, and Kreca). This author found higher values of total phenols and total anthocyanins for the wine produced from Cabernet Sauvignon. Diverse results were found by Pantelić et al. [86], which revealed that the red wine from Serbian variety Prokupac grown in Central Serbia showed higher values of total phenols, (+)-catechin, and (−)-epicatechin compared with the wines from Cabernet Sauvignon, Merlot, Cabernet Franc, Syrah, and Pinot Noir produced in the same wine region. The differences in the conditions of the terroirs in these last two studies had significant impact on the values of the abovementioned parameters.

In Spain, namely in Galicia region (Northwestern Spain), where wine production is mainly focused on white wines, several monovarietal white wines produced from native (Albariño, Branco Lexitimo, Caïño Blanco, Godello, Loureiro, Torrontes, and Treixadura) and non-native (Chardonnay, Gewürztraminer, Pinot Blanc, Pinot Gris, Riesling, and Sauvignon Blanc) varieties were study [88]. This study reported that the wines produced from native varieties had a clear differentiation by their phenolic composition. Specifically, Caïño and Treixadura wines showed the highest total phenolic content, while Riesling presented the highest values among wines produced from non-native varieties (although with values below those observed for native varieties). In China, Li et al. [89] compared the phenolic and chromatic characteristics of red wines produced from native (Vitis amurensis and its hybrids, and Vitis davidii) and several international (Pinot Noir, Marselan, Cabernet Sauvignon, and Syrah) varieties. For these authors, there are specific phenolic compounds that could be recognized as phenolic fingerprints of wines, which could explain their chromatic differences. For example, wines produced from native Chinese varieties had relatively higher blue % value and lower red % value compared with wines obtained from international varieties.

The Cabernet Sauvignon grape represents about 7% of the vineyard area in Argentina. Recently, Muñoz et al. [31] studied the chemical and sensory characteristics...
of the Cabernet wines in different geographical regions during 2018 and 2019 vintages. They concluded that this variety shows a good adaptability to the different Argentina wine regions; however, the selection of the plant material (different clones) combined with the terroir determines the quality attributes of the wines produced.

Table 3 shows results for some wine phenolic compounds for several red wine produced from different international varieties (Cabernet Sauvignon, Merlot, Syrah, Pinot Noir, and Malbec) cultivated in the main South American wine producers. By the data show in this table, it is clear a great diversify of the wine phenolic content. For total anthocyanins, a high variation of values is found, varying between 69.4 and 310 and 681.8 mg/l, for Cabernet Sauvignon wines produced in Brazil and Argentina, respectively. In addition, Malbec wines from Argentina show the highest total average anthocyanin content [90–92]. Recently, also in Brazil, a few authors reported for Merlot wines produced in high altitude regions of the State of Santa Catarina, high concentrations of hydroxycinnamic acids and several volatile compounds, such as phenylethyl acetate, ethyl cinnamate, and γ-lactone, which contribute to the aromas of coconut, peach, roses, honey, and red fruits. All this content observed was comparable with the results obtained for red wines produced from this grape variety from other regions and countries [94]. Faustino et al. [95] reported a comparative analysis of phenolic composition of selected American, Chilean, and Canadian Merlot wines. These authors concluded that the different climatic regions have an important role of Merlot wines phenolic composition. Thus, Chilean Merlot wines tended to have higher flavonoid content, while Canadian wines showed intermediate values, and American wine had the lowest flavonoid values. The results obtained also demonstrated that moderate average temperatures provide Merlot wines with high phenolic content.

For Syrah wines obtained from grapes cultivated in two regions with different altitudes in Northeast Brazil and during two vintages (2014 and 2015), it was demonstrated that chemical composition of wines was influenced by altitude. In that case, wines obtained from higher altitude (1100 m) region showed the highest phenolic composition. However, for sensory profile, floral, herbaceous, fruity, and empyreumatic aromatic attributes were obtained in Syrah wines from the 350 m altitude region [96]. Also, a study published by Fushing and colleagues [76] reported the relationships between chemical and sensory characteristics of Malbec wines in connection with their regions of production. According to these authors, there is a more marked regionality in Argentinian Malbec wines compared with Californian Malbec wines.

In addition, King et al. [97] also reported for Malbec wines from Mendoza region (Argentina) that generally they show more ripe fruit, sweetness, and higher alcohol levels, while the Californian Malbec wines have more synthetic fruit and citrus aromas and bitter taste. Compositional differences between the wines from these two countries were related more to altitude than precipitation and growing degree days. In fact, the viticultural sites in Mendoza, Argentina, are located at much higher elevations (on average, 1103 ± 133 m above sea level), than those in California (on average, 190 ± 200 m above sea level).

Table 4 summarizes several results obtained for general chemical analytical parameters and phenolic composition of different monovarietal red wines produced from Malbec, Bonarda, Cabernet Sauvignon, Merlot, Syrah, and Tempranillo varieties in Mendoza, Argentina. The results found by Fanzone et al. [92] in this region are indicative of the polyphenolic richness of Malbec compared with the other red varieties and their potential to produce quality wines. Titratable acidity varied from 4.4 to 6.8 g/l, pH from 3.60 to 3.84, and ethanol content from 13.0 to 15.2%. These parameters influenced the sensory quality and microbiological stability of the wine.
<table>
<thead>
<tr>
<th>Varieties/countries</th>
<th>Phenolic compounds</th>
<th>Total anthocyanins</th>
<th>Cinnamic acids</th>
<th>Flavan-3-ols</th>
<th>Benzoic acids</th>
<th>Stilbene</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>p-coumaric acid²</td>
<td>Caffeic acid²</td>
<td>(+)-Catechin²</td>
<td>(-)-Epicatechin²</td>
<td>Gallic acid²</td>
</tr>
<tr>
<td>Cabernet Sauvignon</td>
<td>Brazil</td>
<td>69.4–310¹</td>
<td>8.02</td>
<td>4.62</td>
<td>76.46</td>
<td>25.64</td>
</tr>
<tr>
<td></td>
<td>Argentina</td>
<td>681.8³</td>
<td>4.81</td>
<td>2.74</td>
<td>116.18</td>
<td>24.03</td>
</tr>
<tr>
<td></td>
<td>Chile</td>
<td>246.0⁴</td>
<td>4.98</td>
<td>4.95</td>
<td>125.61</td>
<td>29.65</td>
</tr>
<tr>
<td>Merlot</td>
<td>Brazil</td>
<td>89.1–310⁵</td>
<td>10.73</td>
<td>3.61</td>
<td>64.39</td>
<td>25.88</td>
</tr>
<tr>
<td></td>
<td>Argentina</td>
<td>644.1¹</td>
<td>7.56</td>
<td>3.03</td>
<td>85.57</td>
<td>20.12</td>
</tr>
<tr>
<td></td>
<td>Chile</td>
<td>109–121¹</td>
<td>7.51</td>
<td>4.87</td>
<td>149.14</td>
<td>30.69</td>
</tr>
<tr>
<td>Syrah</td>
<td>Brazil</td>
<td>921–386⁶</td>
<td>6.97</td>
<td>5.42</td>
<td>121.17</td>
<td>36.39</td>
</tr>
<tr>
<td></td>
<td>Argentina</td>
<td>301.4³</td>
<td>5.58</td>
<td>4.21</td>
<td>83.36</td>
<td>22.73</td>
</tr>
<tr>
<td></td>
<td>Chile</td>
<td>74.5–199³</td>
<td>6.88</td>
<td>4.91</td>
<td>86.94</td>
<td>39.51</td>
</tr>
<tr>
<td>Pinot Noir</td>
<td>Brazil</td>
<td>100.36¹</td>
<td>6.17</td>
<td>3.80</td>
<td>59.15</td>
<td>28.40</td>
</tr>
<tr>
<td></td>
<td>Argentina</td>
<td>—</td>
<td>4.40</td>
<td>4.61</td>
<td>123.02</td>
<td>33.99</td>
</tr>
<tr>
<td></td>
<td>Chile</td>
<td>—</td>
<td>4.97</td>
<td>4.93</td>
<td>93.23</td>
<td>41.72</td>
</tr>
<tr>
<td>Malbec</td>
<td>Brazil</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td></td>
<td>Argentina</td>
<td>1044.5¹</td>
<td>6.91</td>
<td>345</td>
<td>88.62</td>
<td>19.75</td>
</tr>
<tr>
<td></td>
<td>Chile</td>
<td>—</td>
<td>7.21</td>
<td>4.30</td>
<td>67.84</td>
<td>44.53</td>
</tr>
</tbody>
</table>

¹De Andrade et al. [90].
²Granato et al. [91].
³Fanzone et al. [92].
⁴Nascimento et al. [93].

Table 3. Phenolic composition (mg/l) of red wines produced from several international varieties in three South American countries.
### Table 4.
General chemical parameters and individual phenolic composition of several monovarietal red wines produced from Malbec, Bonarda, Cabernet Sauvignon, Merlot, Syrah, and Tempranillo in Mendoza region, Argentina (Fanzone et al. [92]).

<table>
<thead>
<tr>
<th>Parameters/compounds</th>
<th>Malbec</th>
<th>Bonarda</th>
<th>Cabernet Sauvignon</th>
<th>Merlot</th>
<th>Syrah</th>
<th>Tempranillo</th>
</tr>
</thead>
<tbody>
<tr>
<td>Titratable acidity (g/l tartaric acid)</td>
<td>6.8 ± 0.3</td>
<td>5.3 ± 0.2</td>
<td>6.7 ± 0.3</td>
<td>5.8 ± 0.4</td>
<td>4.4 ± 0.2</td>
<td>5.6 ± 0.3</td>
</tr>
<tr>
<td>pH</td>
<td>3.6 ± 0.06</td>
<td>3.8 ± 0.04</td>
<td>3.73 ± 0.09</td>
<td>3.73 ± 0.09</td>
<td>3.8 ± 0.06</td>
<td>3.84 ± 0.07</td>
</tr>
<tr>
<td>Ethanol (% v/v)</td>
<td>15.2 ± 0.4</td>
<td>13.0 ± 0.3</td>
<td>14.5 ± 0.3</td>
<td>14.5 ± 0.1</td>
<td>13.6 ± 0.2</td>
<td>13.8 ± 0.2</td>
</tr>
<tr>
<td>Total phenols (mg/l GAE)</td>
<td>4203.2 ± 412.8</td>
<td>3372.1 ± 453.0</td>
<td>33776 ± 369.6</td>
<td>34475 ± 372.3</td>
<td>15856 ± 50.6</td>
<td>31374 ± 152.9</td>
</tr>
<tr>
<td>Total anthocyanins (mg/l)¹</td>
<td>1044.5 ± 88.2</td>
<td>739.8 ± 55.0</td>
<td>681.8 ± 100.8</td>
<td>644.1 ± 37.6</td>
<td>301.4 ± 18.9</td>
<td>7176 ± 41.9</td>
</tr>
<tr>
<td>Proanthocyanidins (mg/l catechin)</td>
<td>5013.0 ± 507.2</td>
<td>3925.4 ± 556.3</td>
<td>3860.7 ± 439.6</td>
<td>4439.9 ± 498.5</td>
<td>1922.6 ± 160.1</td>
<td>3200.7 ± 250.9</td>
</tr>
<tr>
<td>Malvidin-3-glucoside (mg/l)¹</td>
<td>257.0 ± 8.0</td>
<td>146.2 ± 6.4</td>
<td>141.3 ± 12.2</td>
<td>119.3 ± 10.6</td>
<td>73.7 ± 2.2</td>
<td>162.0 ± 7.6</td>
</tr>
<tr>
<td>Peonidin-3-glucoside (mg/l)¹</td>
<td>40.3 ± 2.4</td>
<td>16.6 ± 1.2</td>
<td>14.9 ± 1.3</td>
<td>14.3 ± 1.0</td>
<td>17.0 ± 1.0</td>
<td>17.0 ± 1.0</td>
</tr>
<tr>
<td>Petunidin-3-glucoside (mg/l)¹</td>
<td>61.8 ± 2.3</td>
<td>28.7 ± 2.0</td>
<td>14.4 ± 0.9</td>
<td>23.2 ± 1.9</td>
<td>6.0 ± 0.3</td>
<td>35.0 ± 0.7</td>
</tr>
<tr>
<td>Cyanidin-3-glucoside (mg/l)¹</td>
<td>5.48 ± 0.28</td>
<td>2.44 ± 0.20</td>
<td>2.10 ± 0.20</td>
<td>2.46 ± 0.17</td>
<td>0.66 ± 0.04</td>
<td>2.42 ± 0.15</td>
</tr>
<tr>
<td>Delphinidin-3-glucoside (mg/l)¹</td>
<td>41.2 ± 2.4</td>
<td>18.9 ± 1.5</td>
<td>10.1 ± 1.0</td>
<td>14.5 ± 1.1</td>
<td>2.7 ± 0.1</td>
<td>26.5 ± 1.5</td>
</tr>
<tr>
<td>Total glucosylated anthocyanins (mg/l)¹</td>
<td>405.8 ± 11.8</td>
<td>212.8 ± 10.1</td>
<td>182.8 ± 14.8</td>
<td>183.8 ± 10.8</td>
<td>974 ± 3.3</td>
<td>242.9 ± 10.8</td>
</tr>
<tr>
<td>trans-Resveratrol-3-glucoside (mg/l)</td>
<td>9.2 ± 1.0</td>
<td>3.2 ± 0.4</td>
<td>2.1 ± 0.3</td>
<td>4.1 ± 0.6</td>
<td>2.2 ± 0.4</td>
<td>1.9 ± 0.1</td>
</tr>
<tr>
<td>(+)-Catechin (mg/l)</td>
<td>52.7 ± 6.5</td>
<td>58.7 ± 5.4</td>
<td>52.2 ± 3.7</td>
<td>44.0 ± 3.5</td>
<td>28.5 ± 5.7</td>
<td>19.9 ± 0.3</td>
</tr>
<tr>
<td>(−)-Epicatechin (mg/l)</td>
<td>21.8 ± 3.3</td>
<td>34.8 ± 3.0</td>
<td>26.0 ± 1.4</td>
<td>31.7 ± 1.9</td>
<td>14.9 ± 3.6</td>
<td>12.3 ± 1.4</td>
</tr>
</tbody>
</table>

¹Values expressed as equivalents of malvidin-3-monoglucoside.
Malbec wines presented higher acidity, lower pH, and higher ethanol content than the other varieties. Total phenols ranged from 1585.6 to 4203.2 mg/l, and Malbec wines showed higher phenolic levels than others, while Syrah wines had the lowest phenolic content. Malbec wines had also the highest content of total anthocyanins and proanthocyanidins.

In Europe, the adaptability of international grape varieties outside from their terroir of origin creates wines with diverse chemical and sensory profiles. Cosme et al. [50] studied the tannin profile of several monovarietal wines obtained from different Portuguese native (Touriga Nacional, Trincadeira, and Castelão) and no native (Syrah and Cabernet Sauvignon) red grape varieties cultivated in Lisbon wine region during two vintages (2004 and 2005). These authors reported similar tannin profiles in each vintage for Trincadeira and Cabernet Sauvignon wines. Monagas et al. [59] reported data about the wine flavan-3-ols composition for Graciano, Tempranillo, and Cabernet Sauvignon wines elaborated under the same conditions and obtained from grapes cultivated in the same geographical area (Navarra, Spain) and also with same technological maturity. These authors described that among the three wines, similar skins’ proanthocyanidin content was obtained. However, Cabernet Sauvignon wines showed a lower mean degree of polymerization of proanthocyanidins than Tempranillo wines.

It is well known that volatile composition is crucial to the quality of wines due to their influence on the aroma profile. For Chardonnay wines produced in Spanish Castilla-La Mancha wine region, a few studies reported that these white wines in general show a high content of several terpenes, such as geraniol, citronellol, and linalool, which provide citric and floral aromas [98, 99]. These contents are even higher than those found in other white wines produced from Spanish native grape varieties [100]. A comparative analysis of the sensory flavor characteristics between monovarietal white wines produced from different native grape varieties cultivated in Turkey and Chardonnay and Semillon wines was studied by Elmaci et al. [101]. The wines produced from the two international white varieties showed specific aroma and flavor characteristics, where notes of green plum for Semillon and banana and tobacco for Chardonnay wines were reported as specific sensory characteristics compared with white wines obtained from native Turkish varieties.

Finally, the continuous increase in global temperatures is leading to the appearance of new wine regions, outside of the traditional regions in the “old world” (Italy, France, Spain, Portugal, among other European countries) and “new world” (Chile, Argentina, South African, Australia, or United States). Thus, new wine-producing countries from different areas, such as the northern parts of Europe, are emerging. In this case, international grapes varieties have been introduced besides the use of a few hybrid cultivars varieties highly resistant to the specific climatic conditions (i.e., frost) and tolerant to oidium, downy mildew, and to some extent also to Botrytis.

Recently, Garrido-Bañuelo et al. [102] compared several Swedish white wines produced from Solaris variety (a hybrid cultivar) with different white wines produced from Sauvignon Blanc (from New Zealand and France), Chardonnay (from France), and Chenin blanc (from South Africa). In general, the differences in taste and mouthfeel were more obvious between Solaris wines and the other white wines produced from the other international varieties independently of the country origin. In England, the vineyard area in 2013 had has grown with Pinot Noir and Chardonnay representing 22 and 23% of vineyard area, respectively. The wines produced from these two international cultivars represent a substantial value of the total wine produced in this country [103].

Lastly, it is important to note that in general, wine consumers attribute a high value to the aspects related to typicality and consequently to native grape varieties.
to produce unique wines. However, this evidence runs parallel to another tendency that moves in the contrary trend, that is, the emergence of “international” tastes among the different consumers, especially in no traditional wine countries producers. Boncinelli et al. [104] reported that the initial wine consumers’ preference for wines with only native grape varieties is contradicted in the post-taste evaluation, where wines containing between 10 and 20% of international grape varieties are in general more valorized than wines containing 100% of native varieties.

5. Final remarks

In this chapter, we focused on the adaptation of most important international grape varieties, originating from traditional wine countries, in different world wine regions characterized by heterogeneous environmental conditions and specific “terroirs.” The adaptability is assessed through the available data on most important productivity parameters, as well as, through grape and wine composition, and sensory profile.

Grape and wine composition of the same vine varieties, but grown in different wine regions of the world, depends on climate factors, such as sunlight exposition, temperature, rainfall, as well as soil type and composition, degree of grape ripeness, and of course on cultural practices involved in grape processing and wine production. Winegrowers had traditionally selected and cultivated foreign grape varieties that best match their specific climate and soil conditions. However, the impact of climate changes on vitivinicultural sector is already obvious in various aspects, causing the experts from different fields focus on research and experimental activities about the adaptive capacity of the most economically important grape varieties to these global changes in different wine regions. Furthermore, the continuous increase in global temperatures resulted in the appearance of new wine regions as well as in the further dispersion of various grape varieties in areas where viticulture was, until recently, very limited. Thus, new wine-producing regions, such as northern parts of Europe and China, and areas in North and South America are emerging. These novel wine regions are oriented on the cultivation of both established grape varieties and relatively new hybrid varieties highly resistant to specific climate conditions (i.e., frost) and tolerant to oidium, downy mildew, and to some extent also to Botrytis. In addition, other important challenges are certainly the clonal selection process of these varieties ensuring the clones with best properties in the specific environments. Thus, the scientific knowledge about the adaptability of different international grape varieties in diverse environments is of great importance for winegrowers worldwide.

Conflict of interest

The authors declare no conflict of interest.
Author details

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