Heat requirements for grapevine varieties is essential information to adapt plant material in a changing climate

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La connaissance des besoins en chaleur des principaux cépages de vigne est une donnée essentielle pour adapter le matériel végétal dans un contexte de changement climatique

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[1]ENITA – ISVV, 1 Cours du Général de Gaulle, CS 40201, F-33175 Gradignan-Cedex ; [2]SupAgro Montpellier ; [3]SGVRCDR Orange ; [4]Agroclim Avignon ; [5]INRA Angers ; [6]Ferme expérimentale Cahors ; [7]IUVV Dijon ; [8]CEFE-CNRS Montpellier ; [9]UMR DGPC Montpellier ; [10]IFV Midi-Pyrénées ; [11]BIVB Beaune ; [12]University Agronomique Thessalonique ; [13]IFV Nîmes ; [14]Embrapa Brésil ; [15]Chambre d'Agriculture Hérault

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Abstract

Precocity for fruit ripening is a genetically determined characteristic that is highly variable from one cultivar to another. In traditional wine-growing regions of Europe, growers have used this property to adapt the vines to local climatic conditions in order to maximize terroir expression. Due to global warming, the choice of later ripening grapevine varieties might be necessary in many regions to maintain late ripening conditions favourable for terroir expression. Hence, precise heat requirement data for each grapevine variety is essential information. Phenology (budburst, flowering, veraison and ripeness) and temperature data have been collected for many varieties in a wide range of locations over a great number of vintages. Heat summations base of 10°C were calculated for each variety to reach key phenological stages. However, a more sophisticated agro-climatic model might be necessary to increase the precision of a classification of varieties according to their precocity.

Key words: Vine, cultivar, phenology, heat requirement, precocity

Introduction

The timing of grape ripening is crucial in wine production. Grapes that ripen too late in the season and therefore are harvested before a desired maturity, result in the production of green, acidic wines. However, when grapes reach maturity early, in the warmest part of the summer, fruit composition is also unbalanced. Sugar may be high and acidity low, but grapes generally lack aromatic expression. In order to obtain high terroir expression in wine production, grapes should ideally ripen in cool conditions at the end of the growing season (van Leeuwen and Seguin, 2006). Timing of fruit ripening in a given situation is related to (1) local climatic conditions and (2) phenological precocity of the of the cultivar. The latter is a genetically determined characteristic that is highly variable from one grapevine cultivar to another. In traditional wine-growing regions of Europe, growers have empirically used variability in phenology to adapt cultivars to local climatic conditions in order to maximize terroir expression. At high latitudes, where the limiting factor for producing high-quality wines is the level of ripeness of the grapes, early ripening varieties have been planted. At low latitudes, where the climate is warmer, late ripening varieties have been planted to avoid quick ripening of the grapes in the hottest part of the summer. As a result, in Europe, grape picking generally takes place between the 10th of September and the 10th of October, despite huge climatic differences between, for example, the Mosel in Germany, Bordeaux in France and Alicante in Spain. In New World countries in the Southern hemisphere, highest terroir expression is obtained with varieties that ripen in March. Due to global warming, grape ripening is ever more precocious in most wine producing regions today

(Duchêne and Schneider, 2005). In this context, the choice of later ripening grapevine varieties might be necessary in many regions to maintain late ripening conditions favourable for terroir expression. Precocity of phenology for a set of cultivars can be determined when they are planted side by side in one location. It can also be modelled by means of agro-climatic indices. Huglin modelled heat requirements for a wide range of grapevine varieties by means of the so-called "indice héliothermique" (Huglin 1978; Huglin and Schneider, 1998). The latter sums the half of daily average and daily maximum temperatures from April 1 to September 30. Despite this novel approach of modelling heat requirements for cultivars, the data published by Huglin is not very precise: temperature sums required for Cabernet franc to reach maturity are lower then those for Merlot, while Sauvignon blanc and Cabernet-Sauvignon have similar heat requirements. This is not consistent with general observations in Bordeaux, where picking starts with Sauvignon blanc, followed by Merlot and Cabernet franc and ends with Cabernet-Sauvignon. Cabernet-Sauvignon reaches ripeness generally a month later than Sauvignon blanc. McIntyre *et al.* (1982) published also a chronological classification of grapevine phenology. However, this classification is based on mere observations in a cultivar collection over a limited number of vintages. Crop loads and training systems were highly variable. In the present study, the feasibility of establishing a consistent classification for grapevine phenology based on an agro-climatic model is assessed. Several methodological problems have been encountered during this study and pitfalls for this approach are discussed. A possible application of this research is to provide assistance to growers in the selection of new cultivars, when traditional varieties no longer allow high terroir expression due to anticipated maturity induced by global warming. It can also be used to match varieties to local climatic conditions in new wine growing regions where no long term experience is available.

Materials and methods

Phenology data was collected from a wide range of cultivars, including the most widely planted varieties in the world (except Airen which is only cultivated in La Mancha, Spain). Data covered many winegrowing regions over many vintages. Climatic data was gathered from the nearest weather station for each vintage. 10°C is generally considered as the thermal baseline for grapevine development. The Growing Degree Days (GDD) viticultural zoning (Winkler *et al.*, 1974) is based on this assumption. The agro-climatic index that was implemented to model precocity of grapevine phenology was a heat summation with a base of 10°C after January 1. For bud break, GDD were calculated when 50% of the buds reached Baggiolini's B stage (Baggiolini, 1952). For flowering, GDD were calculated when 50% of the flowers were open. For veraison, GDD were calculated when 50% of the berries changes colour (red varieties) or softened (white varieties). Bud break, flowering and veraison data mainly came from "Domaine de Vassal's" (F-34340 Marseillan plage) cultivar collection. Maturity is a phenological stage that cannot be defined with great precision. It is highly dependant on the type of wine the growers intend to produce. Harvest dates in regions where the considered variety is widely planted were treated as the date of maturity for analysis.

Results

Bud break ranged from 40 GDD (Gamay) to 92 GDD (Ugni blanc, figure 1). Cabernet-Sauvignon is also a late budding variety (84 GDD). Most varieties are inside a narrow range between 50 and 60 GDD. Some differences seem inaccurate. Cabernet franc (53 GDD) appears as an early budding variety compared to Merlot (59 GDD), which is generally not observed under field conditions. Flowering ranged from 321 GDD (Gamay) to 414 GDD (Vermentino, figure 2). Other early flowering varieties are Pinot gris (333 GDD) and Pinot noir (334 GDD). Ugni blanc (411 GDD), Mourvèdre (409 GDD) and Tannat (401 GDD) are among the late flowering varieties. Even if this classification for precocity of flowering seems globally consistent, some results are surprising. Merlot (383 GDD) appears as a later flowering variety compared to Cabernet franc (349 GDD), which seems inaccurate. Veraison ranged from 908 GDD (Chasselas) to 1250 (Nebiolo, figure 3). Cabernet-Sauvignon, Xinomavro, Grenache, Petit Verdot, Ugni blanc and Carignane are among the varieties that need a high temperature sum to reach veraison. Pinot gris, Gewürztraminer, Muscat de Frontignan, Gamay and Sémillon are classified as early varieties with regard to their veraison date. For maturity, the harvest date was taken in regions where the given variety is widely planted. This approach limited the number of varieties for which reliable data was available. Chasselas (1204 GDD), Pinot noir (1251 GDD), Chardonnay (1267 GDD) and Gamay (1317 GDD) are early ripening varieties (figure 4). Petit Verdot (1672 GDD), Grenache (1693 GDD), Syrah (1722 GDD), Agiorgitiko (1787 GDD), Cinsault (1833 GDD) and Mourvèdre (1940 GDD) are late ripening varieties. This classification seems globally consistent. However, it is surprising to find Syrah and Petit Verdot as later ripening varieties compared to Cabernet-Sauvignon.

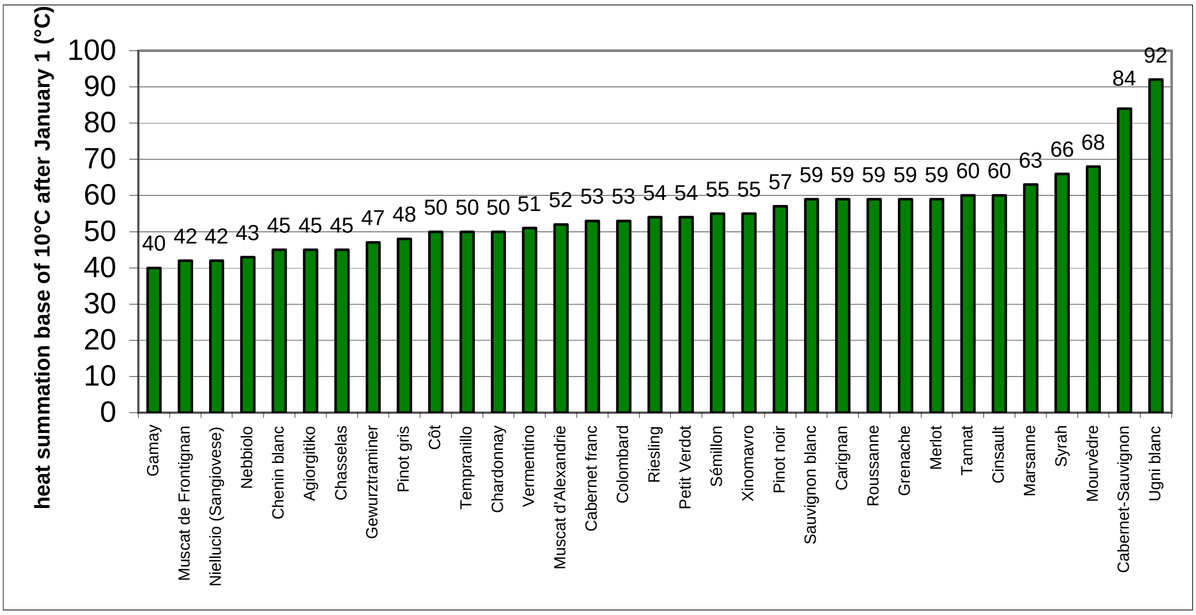

Figure 1 Temperature sum base of 10 necessary to reach bud break for a wide range of grapevine varieties

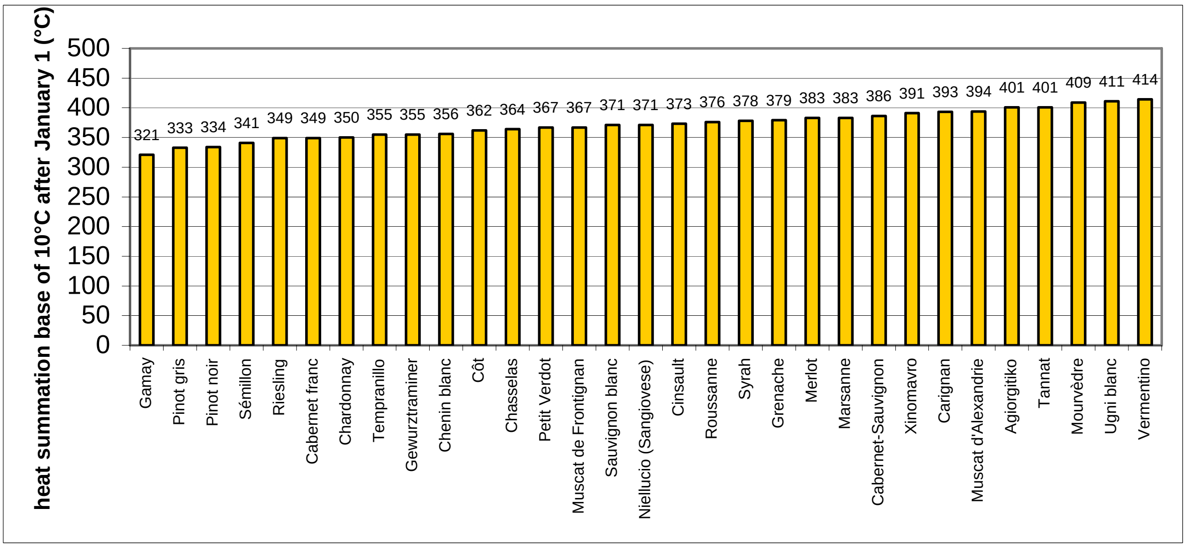

Figure 2 Temperature sum base of 10 necessary to reach flowering for a wide range of grapevine varieties

Discussion

For this study, data was collected from a great number of research stations and private wine producing companies, mainly in France, but also in other European countries. Although phenological stages are monitored in several grapevine cultivar collections, there is no consistent data available covering the four main phenological stages, in one place, over a long period of time. The most complete data set was found at the Domaine de Vassal (F-34340 Marseillan plage). This data set was reliable for bud break, flowering and veraison, but not for maturity.

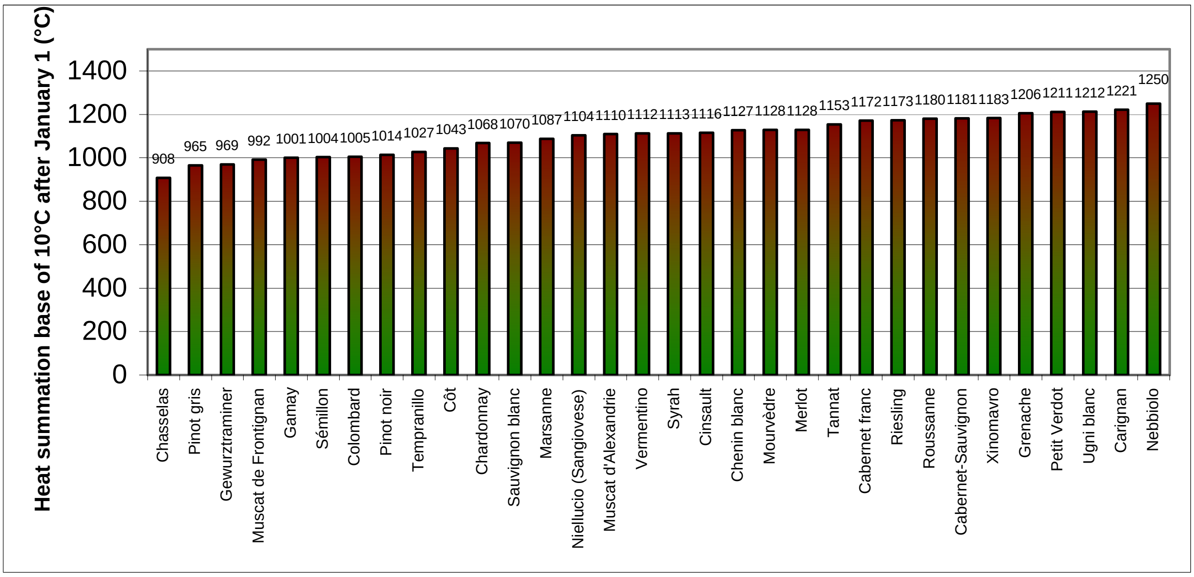

Figure 3 Temperature sum base of 10 necessary to reach veraison for a wide range of grapevine varieties

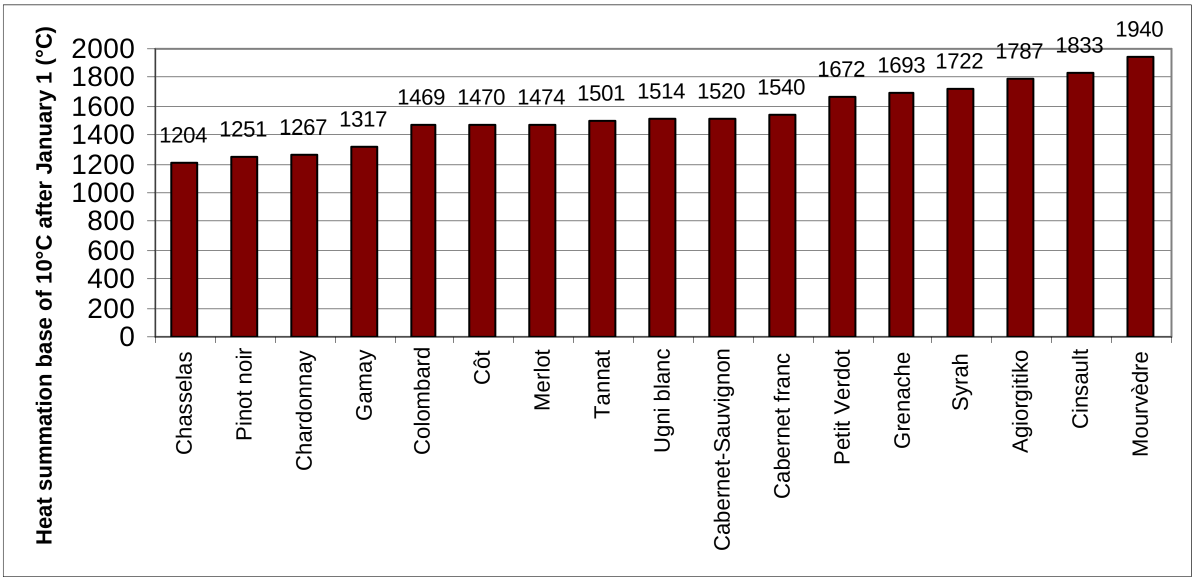

Figure 4 Temperature sum base of 10 necessary to reach maturity for a wide range of grapevine varieties

No consensus exists for the assessment of budbreak. Bud break is most widely noted when 50% of the buds reach Baggiolini's stage C because it is easy to observe. However, some institutes (among them Domaine de Vassal) consider bud break when 50% of the buds reach Baggiolini's stage B, which is probably a more correct definition of bud break. Because the most complete data set with regard to bud break came from Domaine de Vassal, in this study Baggiolini's stage B was taken into account for bud break.

Huglin (1978) considers maturity when grape juice reaches a sugar content of 200 g/L. However, data about the day at which grapes reach a sugar content of 200 g/L is not widely available. Moreover, not all grapevine varieties reach maturity at similar sugar levels. Cabernet-Sauvignon might be completely ripe at a sugar level of 190 g/L, whereas Merlot will only be ripe at a sugar level of 220 g/L. For these reasons, harvest date was considered as being the maturity date.

Temperature sums for the maturity date for a given variety were widely variable from one vintage to another and from one location to another, and so were temperature sums for budbreak. Temperature sums for veraison were more consistent. The least variation was observed for the temperature sums for flowering. Differences among varieties were also smaller for the temperature sums for flowering, compared to other phenological stages.

For a given variety, the temperature sum necessary to reach maturity was higher in warm climates compared to cool climates. Cabernet franc was harvested on average at 1332 GDD in Montreuil Bellay (Loire Valley), at 1520 GDD at Cheval Blanc (Saint-Emilion, Bordeaux) and at 1796 GDD in Montpellier (Chambre d'Agriculture 34). Grapes are probably more mature when picked in warm climates. Wine style might also interfere with harvest date. These are the main pitfalls for considering harvest date as maturity date. To overcome this problem, harvest dates were chosen for each variety in a region where it was considered well adapted. Furthermore, the agro-climatic model used gives a particularly high weight to high temperatures. Photosynthetic processes reach a maximum at 25°C and thus very high temperatures do not necessarily speed up ripening. A more sophisticated agro-climatic model is needed to overcome this drawback. This problem was pointed out by Gladstones (1992). He proposed to cut off average temperatures at 19°C.

Phenology is not only temperature related. Hence, an agro-climatic model cannot perfectly predict vine phenology. Bud break is related to pruning date. It is also related to soil type: dry soils, or soils with shallow rooting, warm up more quickly in the spring and thus speed up budding (Barbeau *et al.*, 1998). Ripening speed which is defined by the interval between veraison and maturity, is influenced by vine water uptake conditions. It has been shown that water deficit increases berry ripening speed (van Leeuwen and Seguin, 1994; van Leeuwen *et al.*, 2003), probably because it reduces competition for carbohydrates between shoot growth and grape ripening.

This classification can be used to select grapevine varieties adapted to local climatic conditions in new winegrowing regions. It can also be used to modify plant material in traditional winegrowing regions faced by the challenge of global climate change.

Conclusion

Vine phenology was modelled for a wide range of cultivars by means of an agro-climatic model based on a temperature sum with a base of 10°C. Consistent classifications were produced for the precocity for budbreak, flowering, veraison and maturity. However, some results do not seem to fit with field observations. A more sophisticated agro-climatic model is necessary to improve the accuracy of this classification of precocity of grapevine varieties.

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