IVES Technical Reviews vine & wine
https://doi.org/10.20870/IVES-TR.2022.5580

# Principles of vineyard establishment and strategies to delay ripening under a warming climate

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Some viticultural strategies may offer a natural solution to mitigate the negative effects of global warming in viticulture. Decisions concerning vineyard topography variables, as well as rootstock, variety, clone, training system, row orientation and slope selection may be combined. This allows grape maturation to be delayed by a few days when they are applied separately and by a few weeks if they are applied together. They can be applied to new vineyards as well as to existing vineyards, as for most premium wine producers worldwide it is not an option to replant somewhere else.

## Vineyard location

### . Elevation

High elevation locations can favour the quality of grapes for winemaking, as they allow the ripening process to develop slowly. Viticulturists can take advantage of the adiabatic effect since elevation can produce a decrease in temperature ranging from 0.60 to 0.65 °C per 100 m of elevation. However, towards the end of the century, climatic models predict a decrease of 0.41 to 0.49 °C per 100 m of elevation[1]. Grapes produced in high elevation vineyards are usually balanced in terms of acidity, nitrogen, phenolic and volatile compounds, and soluble solids content[2]. These characteristics favour the production of wines with low alcoholic degrees and high aromatic quality, acidity and freshness. Nonetheless, some landscape characteristics can cause climatic distortions, interrupting the continuity of elevation-related cooling, such as lack of precipitation, low cloudiness and strong solar radiation, which are typical of some viticultural regions[3]. Elevation is one of the main factors to affect bud break and bloom dates in alpine environments, influencing grapevine response and acrotony phenomenon. As the vineyard elevation increases, phenological events have a longer duration and may produce a difference of up to 21 days in terms of harvest date[4]. This information could be critical in the future since for the 2021-2099 period, harvest timing could decrease by 3 days per 100 m, causing a more concentrated harvest window[1].

### . Latitude

Climate change has also affected grapevine variety distribution in different wine growing regions. Bioclimatic indices suggest that climate change will have negative effects on vine cultivation in southern Europe, while in central and western Europe it could benefit wine quality and allow new areas to be used for viticulture[5]. Similar effects are observed in Chile, in which vineyard plantation is moving south; for example, vineyard surface in Araucanía Region (37°35′ to 39°37′ South latitude) increased by 953 % from 2003-2020. Although latitude can affect the thermal conditions of grapevine development, its effect within a specific area is practically null, but it could be of interest if viticulturists want to experiment and study new terroirs with territorial identity.

### . Slope

Slope can affect water movement and erosion, soil drainage, ease of working among grapevines, mechanisation and ease of harvest.

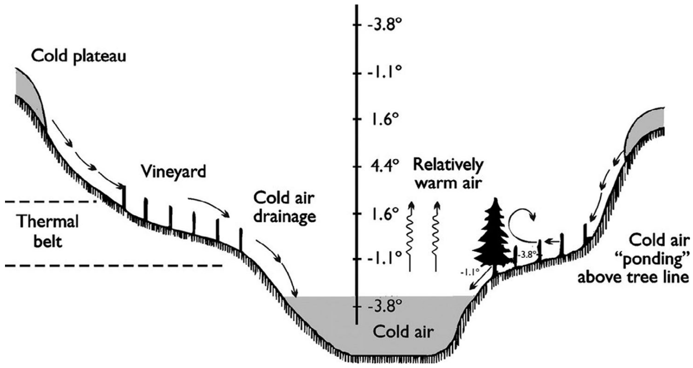


**FIGURE 1.** Effect of topography on air temperature stratification during a radiational cooling period characterized by calm winds and clear skies. Figure published by Barclay Poling[6].

Flat vineyards may be prone to cold air inversions in zones with spring cold frost, while a 5-7.5 % slope allows a good air drainage (Figure 1)[6]. Slope may increase erosion and mechanisation concerns due to the risk of rollover, as well as make grapevine management more difficult. Radiation received by grapevines can be determined by slope direction and steepness, along with vineyard elevation.

## Plant Material

### . Late ripening varieties

Grapevine variety can strongly influence grape ripening, with a difference of close to 2 months having been recorded between the earliest and latest ripening of the varieties of DOCa Rioja (Table 1). Thus, some winegrowing regions should incorporate a higher proportion of late maturing grapevine varieties. In DOCa Rioja, the crop area of Graciano, Mazuelo and Garnacha should probably be increased. In Bordeaux, the proportion of Cabernet Sauvignon should be increased since it matures 2 weeks later than Merlot. In Chilean Central Valley, the proportion of Carménère should probably be increased rather than Cabernet Sauvignon, since it has a late maturation cycle, such as Petit Verdot and Mourvèdre.

### . Rootstock selection

Rootstocks have a slight influence on the phenological cycle of the scion; it is estimated that the difference in terms of harvest date altered by rootstocks is around 2 and 6 days, depending on vineyard yield. Some rootstocks, such as 110 Richter, 140-Ruggeri and 1103 Paulsen,

**TABLE 1.** Mean harvest date, must physico-chemical parameters and grapevine yield for minority grapevine varieties cultivated in the Rioja DOCa (Spain) from the 2009 and 2010 seasons.

| Variety | Havest date | Soluble solids (ºBrix) | pH | Total acidity (g/L)* | Malic acid (g/L) | Tartaric acid (g/L) | Yield (kg/vine) |
|---|---|---|---|---|---|---|---|
| *Red* | | | | | | | |
| Moristel | 29 Sept | 19.7 | 3.25 | 6.27 | 2.45 | 4.94 | 5.01 |
| Vidadillo | 29 Sept | 18.1 | 3.24 | 6.07 | 2.01 | 4.79 | 3.27 |
| Alicante Bouschet | 29 Sept | 19.9 | 3.33 | 6.66 | 2.57 | 4.23 | 7.80 |
| Mandón | 30 Sept | 21.4 | 3.37 | 5.47 | 1.67 | 5.08 | 4.75 |
| Tinto Velasco | 29 Sept | 18.9 | 3.44 | 5.62 | 2.49 | 4.03 | 4.72 |
| Agawan | 16 Sept | 21.8 | 3.20 | 6.76 | 1.72 | 4.84 | 1.26 |
| Portugieser Blau | 16 Sept | 21.8 | 3.34 | 4.89 | 2.77 | 4.13 | 3.41 |
| Morrastell Bouschet | 29 Sept | 17.7 | 3.26 | 5.85 | 2.35 | 4.76 | 5.44 |
| Garnacha Roya | 22 Sept | 19.9 | 3.01 | 7.20 | 2.02 | 6.55 | 5.85 |
| Trepat | 29 Sept | 18.0 | 3.10 | 6.43 | 2.33 | 4.72 | 7.72 |
| Tempranillo Royo | 16 Sept | 24.0 | 3.30 | 5.65 | 2.83 | 4.04 | 4.95 |
| Morate | 29 Sept | 22.1 | 3.32 | 6.72 | 3.10 | 5.13 | 7.59 |
| Petit Bouschet | 29 Sept | 19.4 | 3.43 | 5.44 | 2.63 | 4.50 | 4.39 |
| Maturana Tinta | 29 Sept | 23.1 | 3.85 | 4.81 | 2.37 | 3.30 | 3.35 |
| *White* | | | | | | | |
| Garnacha Blanca | 22 Sept | 22.0 | 3.03 | 7.43 | 0.64 | 4.37 | 3.65 |
| Malvasía de Rioja | 28 Sept | 20.7 | 3.31 | 5.78 | 0.66 | 3.45 | 4.39 |
| Maturana Blanca | 3 Sept | 22.7 | 3.09 | 7.57 | 1.34 | 4.44 | 2.64 |
| Tempranillo Blanco | 3 Sept | 23.3 | 3.25 | 7.40 | 2.07 | 3.39 | 2.60 |
| Turruntés | 28 Sept | 21.7 | 3.22 | 6.37 | 1.22 | 3.19 | 4.26 |
| Viura | 25 Sept | 21.7 | 3.17 | 6.30 | 0.97 | 3.49 | 4.93 |

*As g/L of tartaric acid. Each value corresponds to a mean between the data obtained from 2009 and 2010 seasons.

have been reported as being well adapted to thermal conditions and may provide a long-vegetative cycle compared to Riparia rootstocks[7].

**. Minority and autochthonous varieties**

The disappearance of a wide number of vine varieties and the homogenisation of the wine industry has caused a genetic vulnerability with respect to acclimation to abiotic and biotic stress, to which these varieties are not well adapted. Minority and autochthonous varieties have many genetic resources that would ensure better performance against global warming and resistance to pests and diseases. In DOCa Rioja, the most interesting red minority grapevine varieties that achieve high acidy and low pH are Garnacha Roya, Alicante Bouschet Trepat, Morate and Agawan, and the most interesting white grapevine varieties are Maturana Blanca and Garnacha Blanca (Table 1). Based on this, winemakers should consider these exceptional opportunities to bring a wide range of wine styles with a distinctive identity to the wine market.

## Training system and row orientation

The Gobelet training system could mitigate drought and thermal stress since it results in more porous vegetation, with more ventilation and homogeneous microclimate than vertical shoot position systems. Under these conditions, there is no impediment to the leaves being moved by the wind action, which changes the angle of incidence of solar radiation, allowing the vine to adapt to the increase in temperature through paraheliotropy (Figure 2). Training systems determine cluster and vegetation height above the soil[8]. Trunk height elevation from 45 to 120 cm can reach an average ripening delay of 8 days[8]. The trellising system could play a key role in mitigating or magnifying the positive and negative viticultural effects of row orientation[9]. The vertical shoot position trellis system may not dissipate thermal stress like the gobelet system does, so great care must be taken when choosing the row orientation These strategies must be decided when establishing the vineyard, so that they do not entail additional costs to the annual management of the vineyard and can be classified as preventive viticultural strategies against climate change.

To obtain balanced fruits at harvest, the vineyard should be oriented towards the least favourable exposure to solar radiation. Thus, the best row orientation would be the one that intercepts less solar radiation in the middle of the afternoon. In the Southern Hemisphere, rows orientated east to west maintained the lowest canopy light interception,


**FIGURE 2.** Left: Free standing grapevines (gobelet). Right: Comparison of vertical shoot position trellis system (espaldera) and free-standing grapevines (cordon libre).

whereas the north to south orientation displayed the highest light microclimate values, peaking in the morning and afternoon. Recently, it was demonstrated that leaf water potential was low in northeast to southwest oriented vines in the Southern Hemisphere. This report also concluded that the north to south and the east to west orientated canopies generally showed the highest average photosynthesis[10]. In the Northern Hemisphere, compared to northeast to southwest row orientation, the north to south oriented vines are more sensitive to thermal stress since, in the middle of the afternoon, the west face of the trellis system receives direct solar radiation, coinciding with the highest temperatures of the day. Based on this, rows of new vineyard plantations should be differentially oriented, according to slope and harvest time and critical period of insolation of each variety.

In conclusion, under a warming climate it would be appropriate to select a vineyard orientation that leads to less solar radiation interception and to establish vineyards at higher elevations, with late ripening varieties, clones and rootstocks. The effects of row orientation and slope, though interesting, are not as statistically significant as the effects of elevation. These techniques could be combined with others, such as late winter pruning, double cropping, severe shoot trimming and leaf removal among others, to achieve a ripening delay of up to two months in some cases. ■

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