# INFLUENCE OF EDAPHO-CLIMATIC FACTORS ON GRAPE QUALITY IN CONCA DE BARBERÀ VINEYARDS (CATALONIA, SPAIN)

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**Abstract**

**Aims**: Soil and climate of 3vineyards located in Catalonia (Spain) have been characterized in order todetermine their influence on grape quality (yield and berry composition).

**Methods and results:** All 3 plots are very close, so only interannual climatic data of the nearest meteorological station have been considered. Besides determining chemical and physical properties of soils, the soil water availability has been characterised using capacitance sensors for the period from 2003 to 2005. Both yield and berry composition data were available from Miguel Torres Winery. Climatic data and water availability explained 70% of vintage variability and soil data explained 28% of vintage variability. The edapho-climatic factors had generally a high power of estimation of yield and quality of grapes ($R2 > 0.75$). Climate appeared to be the most influencing factor, followed by water availability, in particular for models referring to must data. Generally, soil data had influence on yield and some must data.

**Conclusion**:The edapho-climatic data explain most of the vintage variability and have a high power of estimation on grape quality.

**Significance and impact of study**:This study remarks the importance of a global approach which takes inot account at least climate and soil water availability to understand the functioning of vines and evolution of berry composition.

**Keys words**: vineyard soil, Mediteranean climate, terroir, soil moisture, grape quality

**Résumé**

**Objectifs**: Le sol et le climat de trois vignobles situés en Catalogne (Espagne) ont été caractérisés pour déterminer leur influence sur la qualité du raisin (production et composition des baies).

**Méthodes et résultats :** Les trois parcelles étudiées sont très proches, on a donc considéré les données climatiques interannuelles d'une seule station météorologique. En plus des propriétés physiques et chimiques du sol, la disponibilité en eau du sol a été caractérisée à l'aide des sondes de capacitance pour la période de 2003 à 2005. Les données de la qualité du raisin (production et composition des baies) sont issues de la Bodega Miguel Torres. Les données climatiques et la disponibilité en eau du sol expliquent les 70 % de la variabilité de la vendange et les données du sol les 28 %. Les facteurs édapho-climatiques ont un haut pouvoir d'estimation de la production et la qualité du raisin ($R2 > 0.75$). Le climat est le facteur le plus influent, suivi de la disponibilité en eau. Le sol, quant à lui, a une influence sur la production quantitative et sur quelques composantes qualitatives du moût.

**Conclusion**: Les données édapho-climatiques ont un haut pouvoir d'estimation de la qualité du raisin et expliquent la plupart de la variabilité de la vendange.

**Signification et impact de l'étude**: Cette étude remarque l'importance d'une approche globale qui prend au moinsen compte le climat et les réserves en eau du sol pour mieux comprendre le fonctionnement des vignes et l'évolution de la composition du raisin.

**Mots clés**: sol viticole, climat méditerranéen, terroir, humidité du sol, qualité du raisn

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## INTRODUCTION

The main objective of modern oenology is to elaborate wines of recognised quality and typicality. This quality is often associated to very especial conditions of soil, climate, cultural practices, training system, in interaction with a variety, which form the concept of terroir (FALCETTI, 1994; VAUDOUR, 2003; DELOIRE *et al.*, 2005). This terroir generally is defined as a spatial and temporal entity, which is characterised by an interaction between the environmental potentialities and viticultural and enological technologies, significant for grapes and/or wine (VAUDOUR, 2003; DELOIRE *et al.*, 2005). There are few studies that consider all the factors of the ecosystem as a whole (VAN LEEUWEN *et al.*, 2004), however some investigators have identified units of terroir considering different factors (CAREY, 2001; MORLAT, 2001). Probably, climate is the factor that determines with more intensity the suitability of the environment for vineyard growing (HIDALGO, 1999). Soil has an important weight, but often it is studied together with climate, because its effects on wine quality are only consistent under the same climatic conditions (SAAYMAN, 1977; CONRADIE, 1998). The soil properties which have the most influence on grape quality are the physical ones, namely the properties that control the soil water content (SEGUIN, 1986), due to its direct effect on equilibrium between vegetative vigour and grape production (VAN LEEUWEN and SEGUIN, 1994).

The aim of this study was to establish the influence of edapho-climatic parameters on grape quality, in particular on both grape yield and berry composition.

## MATERIALS AND METHODS

### 1. Setting

This study was developed from 2003 to 2005 in three vineyards (Milmanda, Riu Sec and Muralles) situated in Conca de Barberà region (NE Spain), near the Catalan Coastal Range. The sites are located between latitudes 41º 22' 7"N and 41º 24' 8"N and between longitudes 1º 3' 53"E and 1º 5" 24"E. The altitudes are 450 m (Milmanda), 459 m (Riu Sec) and 515 m (Muralles).

### 2. Climate data

All three plots have an homogeneous climate, since they are located less than 1.2 km apart. The climate type is Mediterranean with a continental influence, with a mean annual precipitation of 550 mm and a mean annual temperature of 13.6ºC. The viticultural climate (TONIETTO and CARBONNEAU, 2004) is moderately dry, temperate warm and cool nights.

No differences are expected in mesoclimate between Milmanda and Riu Sec, because both plots have similar topographic characteristics (similar altitude, flat landform). However, Muralles plot differs in topography (higher altitude, north-faced landform), having slightly lower temperatures and solar radiation. In this study, only interannual climatic data of the nearest meteorological station have been used, without considering the slight differences of Muralles mesoclimate.

Climatic data were recorded in an automatic weather station (Espluga de Francolí) of the Meteorological Service of Catalonia, located at 41º 23' 39"N, 1º 6' 1"E and 441 m of altitude. This station is located less than 2 km from all plots, having the same topographic position than Milmanda and Riu Sec. Hourly, daily and monthly data of rainfall, temperature, solar radiation, wind, relative humidity, atmospheric pressure and ETo were available.

Different climatic indices have been calculated for each year of the study: Thermal Index of Winkler (WINKLER, 1962), Heliothermal Index of Huglin (HUGLIN, 1978), Heliothermal Index of Branas (BRANAS *et al.*, 1946), Bioclimatic Index of Hidalgo (HIDALGO, 1980), Bioclimatic Index of Constantinescu (CONSTANTINESCU, 1967), august-september daily temperature range (TONIETTO and CARBONNEAU, 2002), dryness index (TONIETTO and CARBONNEAU, 2004) and cool night index (TONIETTO and CARBONNEAU, 2004).

### 3. Soil data

The chosen plots belong to three representative soil mapping units of the region determined in a very detailed (1:5000) soil map made by Miguel Torres Winery. The soil mapping followed the criteria of the Soil Inventory of Catalonia (BOIXADERA *et al.*, 1989, HERRERO *et al.*, 1993) and the Soil Survey Manual (SSS, 1993).

The Milmanda soil (Table I), classified as Typic Xerofluvent, fine-loamy, carbonatic, mesic (SSS, 2003), is a very deep soil, rich in silt (56.5 %) and carbonates (45.8 %), without stones, moderately well drained and with a high water holding capacity (1,541 $m^3 \cdot ha^{-1}$). The Riu Sec soil, classified as Typic Haploxerept, sandy-skeletal, mixed, mesic (SSS, 2003), is a moderately deep soil, rich in sand (89.4 %) and gravels (60 %) in deep horizons, somewhat excessively drained and with a low water holding capacity (384 $m^3 \cdot ha^{-1}$). The Muralles soil, classified as Fluventic Haploxerept, loamy-skeletal, mixed, active, mesic (SSS, 2003), is a deep loam soil, stony, well drained and with a high water holding capacity (1,522 $m3 \cdot ha^{-1}$).

The soil water content was determined by capacitance sensors (ECHO, Decagon Devices Inc.), continuously


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**Table I - Main analytical data of studied soils at different depths.**

| Soil | Depth (cm) | pH | CE (dS/m) | Organic matter (%) | $CaCO_3$ (%) | Sand (%) | Silt (%) | Clay (%) | Textural class* (SSS, 2003) | Bulk density ($kg/m^3$) | Rock fragments (%) | Moisture at -33KPa (%) | Moisture at -1500 KPa (%) | Water holding capacity (mm/10cm) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Milmanda | 20 | 8.4 | 0.23 | 1.1 | 45 | 23.0 | 55.5 | 21.5 | SiL | 1360 | 0 | 21 | 8 | 17.7 |
| | 40 | 8.4 | 0.22 | 0.9 | 46 | 21.8 | 56.4 | 21.8 | SiL | 1659 | 0 | 21 | 8 | 21.6 |
| | 80 | 8.4 | 0.30 | 1.3 | 47 | 20.8 | 56.1 | 23.1 | SiL | 1450 | 0 | 23 | 9 | 20.3 |
| | 120 | 8.0 | 1.42 | 1.2 | 45 | 15.5 | 58.0 | 26.5 | SiL | 1429 | 0 | 19 | 7 | 17.1 |
| Riu Sec | 20 | 8.3 | 0.40 | 2.0 | 17 | 43.8 | 39.9 | 16.3 | L | 1110 | 22 | 21 | 8 | 11.3 |
| | 40 | 8.5 | 0.19 | 1.0 | 9 | 71.1 | 18.8 | 10.1 | SaL | 1449 | 54 | 12 | 5 | 4.7 |
| | 80 | 8.5 | 0.22 | 0.5 | < 2 | 89.6 | 4.7 | 5.7 | Sa | 1143 | 65 | 5 | 2 | 1.2 |
| | 120 | 8.5 | 0.19 | 0.4 | < 2 | 89.1 | 3.3 | 7.6 | Sa | 572 | 50 | 4 | 2 | 0.6 |
| Muralles | 20 | 8.4 | 0.17 | 1.4 | 4 | 54.6 | 28.5 | 16.9 | SaL | 1128 | 28 | 20 | 8 | 14.1 |
| | 40 | 8.4 | 0.19 | 1.1 | 5 | 46.2 | 34.4 | 19.4 | L | 1463 | 30 | 22 | 10 | 13.6 |
| | 80 | 8.4 | 0.19 | 0.7 | 4 | 45.1 | 37.4 | 17.5 | L | 1070 | 31 | 21 | 9 | 13.2 |
| | 120 | 8.3 | 0.17 | 1.1 | 4 | 52.3 | 30.8 | 16.9 | L | 1038 | 48 | 19 | 9 | 10.6 |

* SiL: silt loam, L: loam; SaL: sandy loam; Sa: sand

(every 30 min) and at different depths (15, 30, 60 and 90 cm). In order to minimise the effect of the internal variability of the soil mapping unit, 3 sensors at 20 m of distance were installed for each depth. To make sensors comparable in different soils, without calibration, a water availability index (WA) was calculated. This WA takes the 100 value when the soil moisture content is at field capacity and the 0 value at the minimum soil moisture observed during the study. Field capacity was determined with the capacitance sensors following heavy rainfall periods. Similar methods were used in different previous studies (LEBON *et al.*, 2003).

## 4. Grape quality data

The Milmanda and Riu sec plots are formed of 20-year-old vines of Cabernet Sauvignon cultivar, grafted onto 140R (Milmanda) and SO4 (Riu Sec) rootstock. The Muralles plot is formed of 13-year-old vines of Grenache noir cultivar, grafted onto R110 rootstock. Vine density is 2,800 (Milmanda) and 3,700 (Riu Sec and Muralles) vines per hectare with vines at 1.2 x 2.8 m (Milmanda) and 1 x 2.2 m (Riu Sec and Muralles) (vine x row spacing). All plots followed similar management: vines were trained to an espalier-type canopy system and were double cordon de Royat pruned, vineyards were dry-land farmed, weeds were controlled by ploughing and there was no subtraction of grape to limit yield.

Data of grape quality were measured directly from containers at the winery entrance, between 25th September and 5th October. Yield ($kg \cdot vine^{-1}$) was determined at the weight bridge and alcoholic degree, pH and total acidity (g tartaric acid/L) were analysed by the Maselli SM-03 Winery Grape Must Analyzer. Both anthocyanins (extracted at pH 3.2, in mg/L) and grape seed ripening (difference between absorbance at 280 nm and anthocyanins at pH 3.2) were measured in laboratory, for Cabernet Sauvignon plots, following the method of SAINT-CRICQ DE GAULEJAC *et al.* (1998).

## 5. Statistical analysis

Data analysis was done by multiple regression, considering data of quality of grapes as dependent variables (DV) and considering edapho-climatic data as independent variables (IV). Correlation matrices and Principal Components Analysis were performed to explore data and make a first selection of variables. The procedure « All possible regressions » was used to select the most representative models (higher $R^2$) with selected variables. Then, assumptions of multiple regression were checked. Independent variables were changed until most of the assumptions were accomplished and, if possible, model was significant (confidence level of 0.05%). The software used was NCSS (HINTZE, 2004).

# RESULTS AND DISCUSSION

During the study period, a great interannual variability of rain (from 366 mm to 756 mm) and mean temperature (from 13.2 ºC to 14.9 ºC) is remarkable (table 2). The wettest year was 2003 (756 $mm \cdot year^{-1}$), with rains concentrated in the beginning and at the end of the


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**Table 2 - Monthly and annual meteorological data from 2003 to 2005 of Espluga de Francolí automatic weather station.**

| Variable | Period | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Year |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Rain (mm) | 2003 | 9.2 | 130 | 38.4 | 21.4 | 92.2 | 11.2 | 4.0 | 53 | 48.8 | 190 | 114 | 43.4 | 756 |
| | 2004 | 2.0 | 68.8 | 68.2 | 88.6 | 60.4 | 10.4 | 50.8 | 1.2 | 34.2 | 37.6 | 1.4 | 71.8 | 495 |
| | 2005 | 0.0 | 27.2 | 12.4 | 2.6 | 46.6 | 7.2 | 1.4 | 19 | 54.2 | 61.2 | 130 | 3.6 | 366 |
| Mean high temperatures (ºC) | 2003 | 10.7 | 10.2 | 17.2 | 19.3 | 23.6 | 31.7 | 31.8 | 33.5 | 25.7 | 18.3 | 13.7 | 9.9 | 20.5 |
| | 2004 | 11.4 | 10.1 | 12.8 | 15.4 | 19.6 | 27.5 | 26.9 | 29.7 | 26.4 | 22.2 | 13.2 | 10.5 | 18.8 |
| | 2005 | 9.0 | 9.2 | 14.8 | 19 | 24.3 | 29.6 | 30.9 | 28.5 | 25.1 | 20.3 | 13.4 | 8.9 | 19.4 |
| Mean temperatures (ºC) | 2003 | 6.8 | 6.3 | 11.0 | 13.2 | 17.3 | 24.3 | 25.1 | 26.2 | 19.7 | 13.9 | 9.5 | 5.9 | 14.9 |
| | 2004 | 7.4 | 4.8 | 7.3 | 10.3 | 13.8 | 20.2 | 20.6 | 23.5 | 20.1 | 16.0 | 7.9 | 6.6 | 13.2 |
| | 2005 | 3.5 | 4.0 | 8.3 | 12.7 | 17.4 | 22.4 | 24.1 | 22.0 | 18.8 | 15.3 | 9.1 | 4.0 | 13.5 |
| Mean low temperatures (ºC) | 2003 | 3.2 | 2.7 | 5.2 | 7.8 | 11.6 | 17.4 | 18.3 | 19.1 | 14.2 | 9.9 | 5.7 | 2.2 | 9.8 |
| | 2004 | 3.8 | 0.6 | 2.4 | 5.3 | 8.4 | 13.4 | 14.9 | 17.7 | 14.6 | 10.7 | 3.5 | 3.0 | 8.2 |
| | 2005 | -0.5 | -0.6 | 2.8 | 6.7 | 10.9 | 15.3 | 17.6 | 16.1 | 13 | 11 | 5.4 | 0.6 | 8.2 |
| Solar radiation ($KJ \cdot m^{-2} \cdot day^{-1}$) | 2003 | 7.0 | 7.7 | 15.1 | 17.7 | 22.3 | 24.4 | 24.3 | 21.5 | 15.5 | 9.7 | 6.6 | 5.6 | 14.8 |
| | 2004 | 7.1 | 9.5 | 13.2 | 16.9 | 20.6 | 23.7 | 17.6 | 19.2 | 15.4 | 11.1 | 7.6 | 4.8 | 13.9 |
| | 2005 | 7.6 | 9.6 | 14.1 | 17.1 | 20.3 | 21.0 | 21.8 | 19.0 | 13.1 | 8.7 | 6.0 | 5.8 | 13.7 |

**Table 3 - Viticulture climatic indices from 2003 to 2005**

| Index | 2003 | 2004 | 2005 |
|---|---|---|---|
| Period of vegetative activity (PVA) (Mean T > 10ºC) | March - October | April - October | April - October |
| Mean temperature during PVA (ºC) | 18.8 | 17.8 | 19 |
| Sum of degree-day during PVA | 4612 | 3809 | 4060 |
| Thermal index of Winkler | 2162 | 1669 | 1920 |
| Heliothermal index of Branas | 7.08 | 4.86 | 5.59 |
| Bioclimatic index of Hidalgo | 9.4 | 9.8 | 15.3 |
| Bioclimatic index of Constantinescu | 12.0 | 18.3 | 28.8 |
| August-september daily temperature range | 12.9 | 11.9 | 12.3 |
| Rainfall april-august | 182 | 211 | 76.8 |
| Dryness index - DI (Geoviticulture CCM System) | -21 | 71.8 | 56.5 |
| Huglin index - HI (Geoviticulture CCM System) | 2672 | 2088 | 2413 |
| Cool night index - CI (Geoviticulture CCM System) | 14.2 | 14.6 | 13 |

vegetative cycle. This year was the warmest (annual mean of 14.9 ºC), so thermal indexes were the highest too (Huglin Index = 2,672) (table 3). In 2004, rainfall was lower (495 mm) than in 2003, but during the growing season was higher, so rainfall april-august was the highest of the period (211 mm). Temperatures were the lowest of the period (annual mean of 13.2 ºC), except for maturation period, as reflected in a high cool-night index (14.6 ºC). In 2005, rain was low during the whole year and very low during the growing season (rainfall april-august = 76.8 mm). Temperatures were intermediate, except for maturation period, where temperatures were the lowest (cool-night index = 13 ºC). In 2003, solar radiation was fairly higher than other years, and in 2004 was slightly higher than in 2005.

Figure 1 shows water availability (WA) evolution from June 2003 to October 2005. Generally, summer WA seems inversely proportional to annual rainfall, and spring WA too. The lowest summer WA (< 20 %) occured in 2003 (Riu Sec) and 2004 (Milmanda and Muralles), when rain and spring WA were the highest (generally, higher than 80 %). The high rain and WA could have favoured vegetative development, and vines would be most water demanding in summer. On the contrary, WA values during 2005 were low (< 60 %) in the first months of the growing season, and summer WA were high (> 20 % in Milmanda and > 40 % in Muralles). Some differences between soil types can be observed. In Riu Sec soil, WA usually is lower than in other soils, probably due to quick drainage and low water holding capacity. In Muralles, WA is


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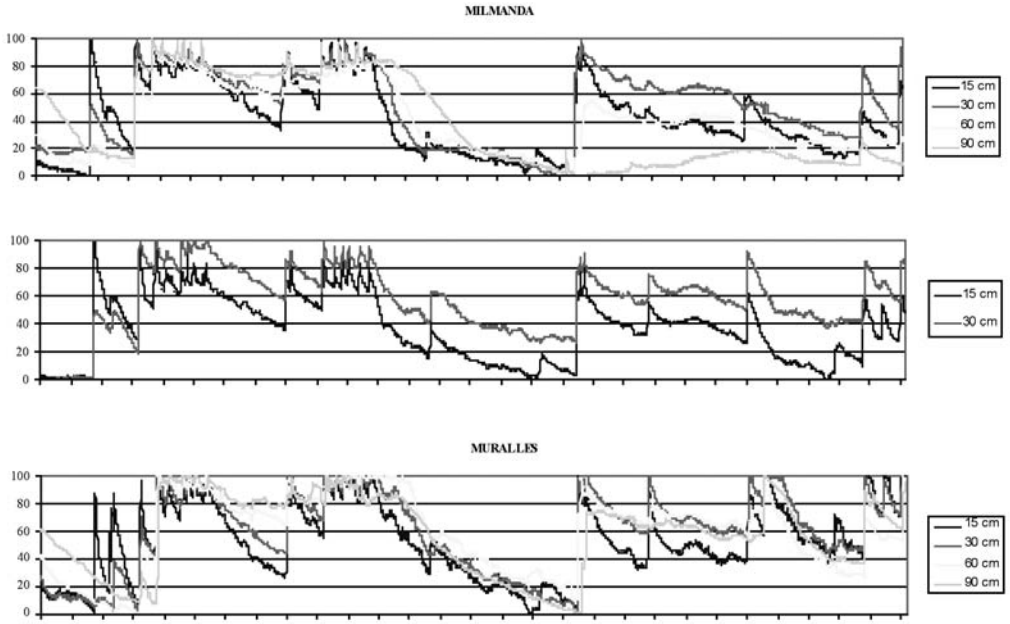



**Figure 1 - Water availability index, in continuum and at different depths, for Milmanda, Riu Sec and Muralles plots**

**Table IV - Data of grape quality for Cabernet Sauvignon (Milmanda and Riu Sec) and Grenache Noir (Muralles)**

| Plot | Milmanda | | | Riu Sec | | | Muralles | | |
|---|---|---|---|---|---|---|---|---|---|
| Year | 2003 | 2004 | 2005 | 2003 | 2004 | 2005 | 2003 | 2004 | 2005 |
| Yield (kg·vine$^{-1}$) | 1.78 | 1.34 | 1.65 | 1.42 | 1.07 | 1.01 | 2.15 | 3.91 | 1.60 |
| Alcoholic degree | 15.3 | 16.1 | 13.3 | 14.5 | 15.5 | 14.4 | 15.8 | 13.7 | 15.6 |
| pH | 3.64 | 3.26 | 3.57 | 3.58 | 3.30 | 3.47 | 3.45 | 3.4 | 3.27 |
| Total acidity (g/L) | 8.81 | 10.67 | 7.13 | 6.21 | 11.1 | 7.26 | 6.02 | 6.55 | 6.38 |
| Grape seed ripening | 10.13 | 8.56 | 7.20 | 17.03 | 3.57 | 7.71 | - | - | - |
| Anthocyanins (mg/L) | 387 | 424 | 318 | 442 | 666 | 540 | - | - | - |

slightly higher than in Milmanda. Between these soils, important differences occur at different depths. During 2005, the horizon at 90 cm depth recovered the WA in Muralles, but not in Milmanda: the rain in Milmanda was not enough to reach field capacity in superficial horizon, so deep horizons did not increase their WA. In Muralles, where water holding capacity is lower, the WA increases at all depths.

The most productive vintage was 2003 in Milmanda and Riu Sec, except for Muralles which suffered an abnormal yield in 2004 (table IV). The vintage least productive was 2005 except for Milmanda (2004): the great development of vegetation could have broken the equilibrium between vegetative activity and fruit production. The highest grape alcoholic degree was in 2004, except for Muralles (2003). The highest pH of must took place in 2003. The highest total acidity took place in 2004. Grape seed ripening had the highest value in 2003, but the minimum value was in 2005 for Milmanda and 2004 for Riu Sec. Anthocyanins had the highest value in 2004, but the minimum value was in 2005 for Milmanda and 2003 for Riu Sec.

Matrix correlations and PCA were done in order to explore data and select the best explicative factors. Figure 2 shows a PCA considering only the selected variables, which is more understandable. Factor 1, which explains 35.98 % of variability, separates 2004 vintage from 2003 and 2005 vintages. 2004 vintage has higher rainfall during October-September (R oct-sep), meanwhile 2003 and 2005 vintages are both characterized by a higher mean daily temperature range for vineyard growing season (TR act). Factor 2, which explains 33.72 % of


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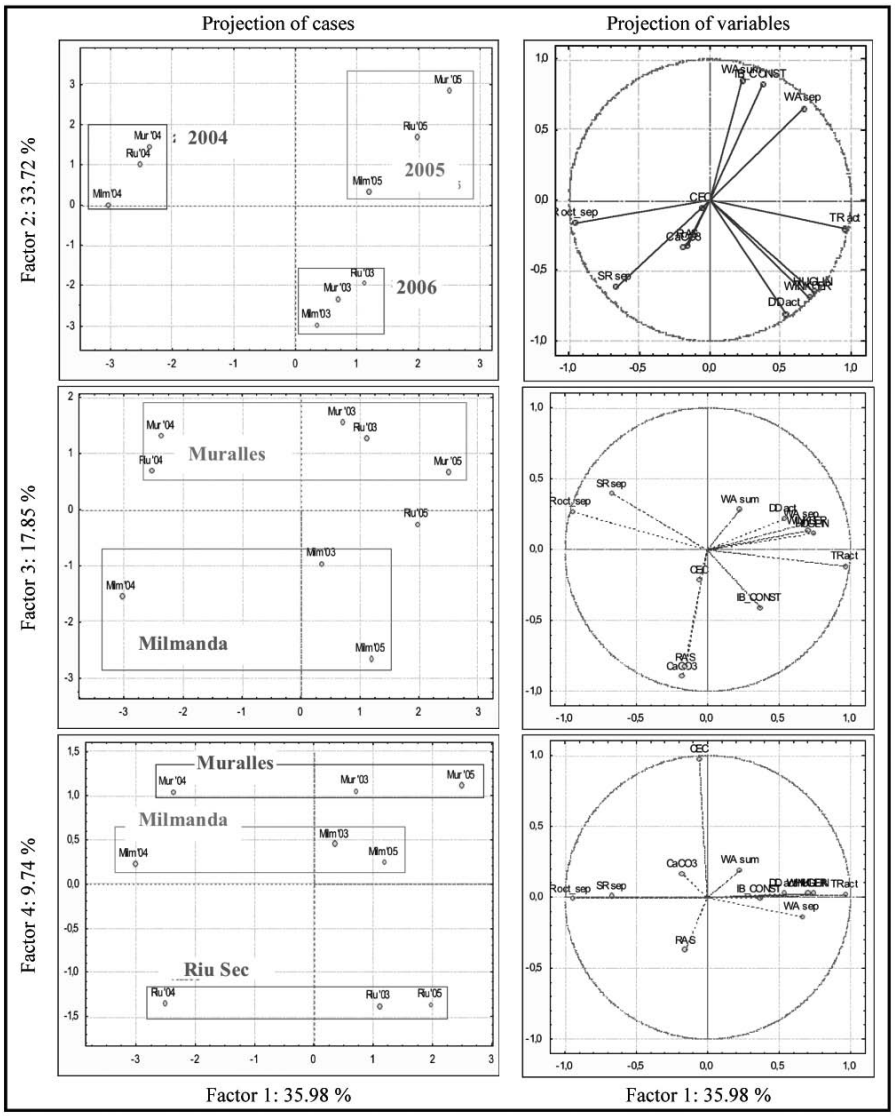



**Figure 2 - Projection of cases and variables on the factor-planes of the PCA performed with selected variables.**
(WA sum: mean WA in summer, WA sep: mean WA in September, CEC: Cation Exchange Capacity, RAS: ratio absorption sodium, SR set: mean daily solar radiation in September, TR act: mean daily temperature range for vineyard growing season, DD act: sum of degree-day for vineyard growing season, R oct-sep: Rain during October-September, Winkler: Winkler index, Huglin: Huglin index, Const: Constantinescu index)

variability, distinguishes between 2003 and 2005 vintages. The 2003 vintage is situated in an area with high thermal indexes (sum of degree-day for vineyard growing season (DD act), Winkler index, Huglin index). On the other side, 2005 is characterised by a high water availability index (WA); year 2004 shows the same trend than 2005. Factor 3, which explains 17.85 % of variability, clearly separates Muralles soil from Milmanda soil, mainly by CaCO3 content and ratio absorption sodium (RAS). Factor 4, explaining 9.74 % of variability, separates each vineyard by its Cation Exchange Capacity (CEC), having Muralles the highest CEC and Riu Sec the lowest one. In conclusion, climatic data and water availabity explain 70 % of variability (factors 1 and 2). For this reason, climate and water availability are the main factors allowing to distinguish vintages, with climate having probably more influence than water availability. Finally, soil data explain 28 % of variability (factors 3 and 4).

Models for grape quality were performed by Multiple Regression Analysis (Table V). These models have a high estimation capacity, with $R^2$ higher than 0.75 (except for pH and grape seed ripening). The models are significant ($p < 0.05$) for yield, total acidity and anthocyanins; and slightly non significant ($0.05 < p < 0.07$) for alcoholic degree, pH and grape seed ripening. Yield is highly correlated with edapho-climatic data ($R^2 = 0.88$). The chosen independent variables are CEC and Winkler Index, with a similar importance (similar standardized regression coefficient). The properties of must can be highly


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**Table V - Results of Multiple Regression Analysis for grape quality variables**

| Dependent variable | Independent variables[1] | Regression coefficient (b) | Model quality | |
|---|---|---|---|---|
| Yield | CEC | 0.6795 ** | $R^2$ | 0.8795 |
| | Winkler index | 0.5566 * | n | 8 |
| | | | Significance (p level) | 0.005 |
| Alcoholic degree | CEC | 0.3619 ns | $R^2$ | 0.8128 |
| | SR september | 1.1050 * | n | 8 |
| | WA summer | 0.8318 * | Significance (p level) | 0.062 |
| Total acidity | R oct-sep | 0.6736 * | $R^2$ | 0.7663 |
| | RAS | 0.8190 * | n | 9 |
| | WA summer | 0.4280 ns | Significance (p level) | 0.049 |
| pH | Huglin index | 0.6092 ns | $R^2$ | 0.6256 |
| | WA summer | -0.3406 ns | n | 9 |
| | | | Significance (p level) | 0.052 |
| Anthocyanins | R oct-sep | 0.5594 * | $R^2$ | 0.9040 |
| | WA summer | 0.8623 * | n | 6 |
| | | | Significance (p level) | 0.030 |
| Grape seed ripening | DD act | 0.791 ns | $R^2$ | 0.6257 |
| | | | n | 6 |
| | | | Significance (p level) | 0.061 |

*, **, ns indicate significance at $p < 0.05$, $p < 0.01$ and nonsignificant, respectively.
1: CEC: Cation Exchange Capacity, SR september: mean daily solar radiation in September, WA summer: mean water availability index in summer, R oct-sep: Rain during October-September, RAS: ratio absorption sodium, DD act: sum of degree-day for vineyard growing season.

estimated, except for pH and grape seed ripening ($R^2$ = 0.63). Anthocyanins is the most correlated variable ($R^2$ = 0.9). In models for must properties, a climatic index (SR september, R oct-sep, Huglin index and DD act) and a water availability index (WA summer) is always present, except for grape seed ripening, where there is only a climatic index (DD act). Climatic indices have higher influence than WA indices, except for anthocyanins, where WA summer has the greatest weight. Soil data appear in alcoholic degree model, having few importance (CEC); and total acidity model, having high importance (RAS).

Climatic data have the highest influence on regression models, as it is shown by the PCA, particularly the climatic indices which estimate must data. These results agree with the conclusions obtained in previous studies (VAN LEEUWEN *et al.*, 2004), where climate appears as the most influencing factor on must quality. It is known the effect of climate, mainly temperatures and solar radiation, on grape maturation and accumulation of phenolic compounds (COOMBE, 1987; JACKSON and LOMBARD, 1993; TONIETTO and CARBONNEAU, 2002).

Water availability is the second important predictor, specially in must data. Water supply to vines strongly influences the quantity and quality of their grape production (OLIVEIRA, 1995; VAN LEEUWEN *et al.*, 2003; HUNTER and DELOIRE, 2005). This can be explained by the effect of water supply on the balance between vegetative and reproductive growth (MATTHEWS *et al.*, 1987; VAN LEEUWEN and SEGUIN, 1994). Grape maturation can improve in case of moderate water limitation, increasing the content of sugars and phenolic compounds, and decreasing acid malic content (TRÉGOAT *et al.*, 2002; OJEDA *et al.*, 2002).

On the other hand, soil characteristics are important to predict yield and total acidity. Generally, it is difficult to establish a direct correlation between soil characteristics and wine quality (SEGUIN, 1986). However, soil properties, mainly nitrogen status and soil depth, can affect grape and wine quality, even more than water supply (CHONÉ *et al.*, 2001).

All the studied parameters have an influence on grapevine functioning in relation with the grape berry development, composition and the evolution of the fruit maturation (BRENON *et al.*, 2005). A global approach


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which takes into account at least edapho-climatic data is necessary to understand the functioning of vines and evolution of berry compostion (DELOIRE *et al.*, 2005).

## CONCLUSION

The effect of both soil and interannual climate parameters on grape quality were studied, without considering cultivar effect and considering the same climate for all plots. As cultivar has an influence on wine typicality, this study is focused on yield and some parameters of berry composition, without analysing implications on wine quality. A water availability index was calculated from soil moisture data measured by capacitance sensors. The water availability index resulted a useful tool to predict grape must quality. However, the style of the wine can not be predicted from this study, since it does not consider cultivar differences. According to the performed PCA, climatic data and water availability explained 70 % of vintage variability and soil data explained 28 % of vintage variability. Climatic data seemed slightly more explicative than water availability. The Multiple Regression Analysis showed that edapho-climatic factors had generally a high power of estimation of yield and quality of grapes, with $R^2$ higher than 0.75. All models were significant at 90 % probability ($p < 0.07$). Climate appeared to be the most influencing factor, followed by water availability, in particular for models referring to must data. Climatic data used in models were climatic indices, as Huglin index or Winkler index. The selected water availability index was the mean water availability in summer. Generally, soil data had influence on yield and some must data.

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