

HIERARCHY OF SEVERAL FACTORS MAKING PART OF THE TERROIR EFFECT AND THE ROLE OF VINE WATER SUPPLY

La hiérarchie des facteurs de l'effet terroir et l'influence du régime hydrique de la vigne

C. van Leeuwen

Professeur de viticulture

ENITA de Bordeaux - ISVV

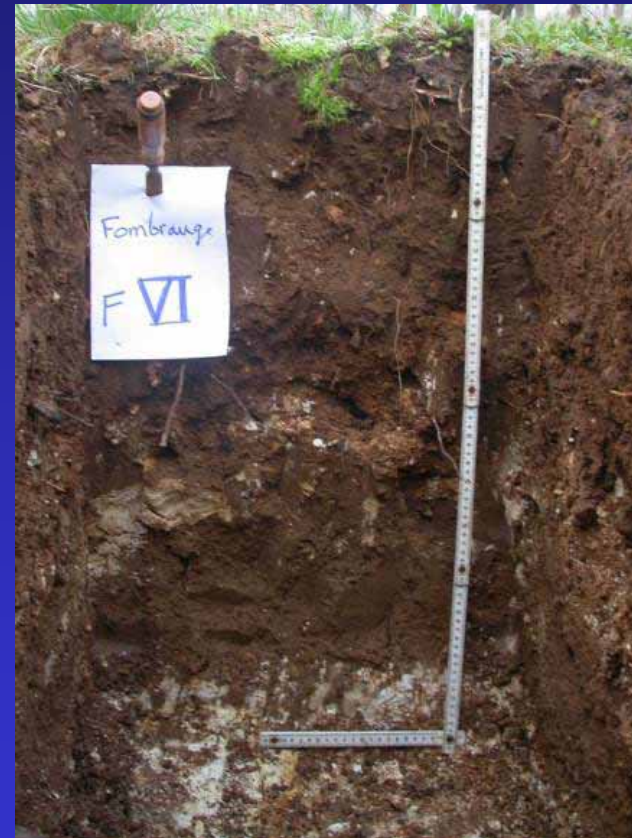
U.M.R. Ecophysiologie et Génomique Fonctionnelle de la Vigne



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Terroir effect in viticulture

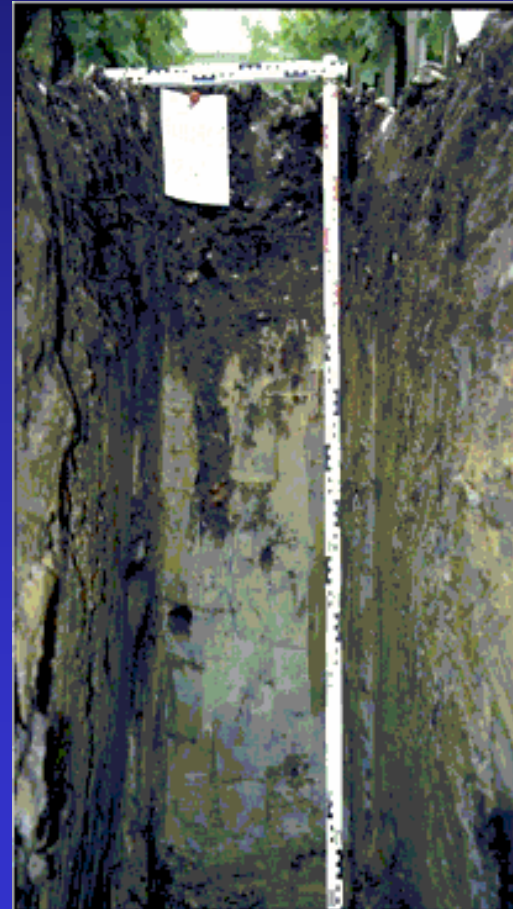
- Terroir can be defined as « an ecosystem, managed by man, in which the vine interacts with environmental factors (soil, climate)



Soil is an important factor in terroir expression

- **soil**

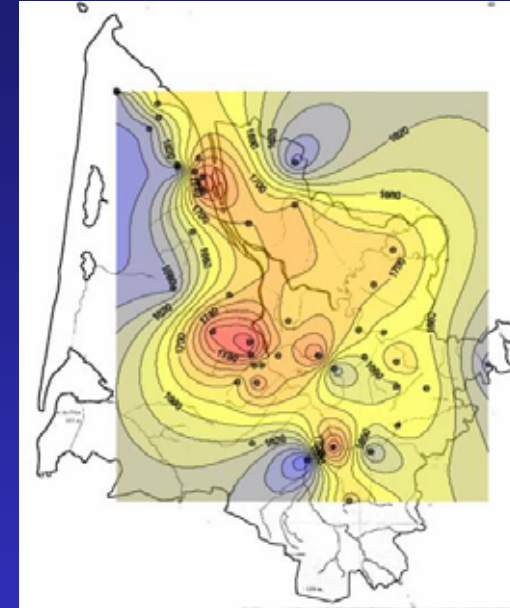
- Geological origin
- Soil type
- Soil depth
- Water holding capacity
- Soil organic matter content
- N dynamics
- Other soil minerals



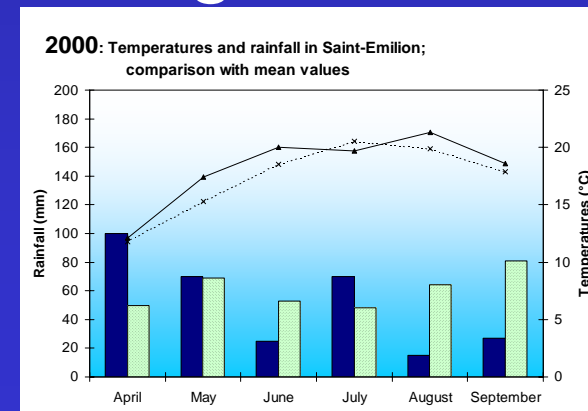
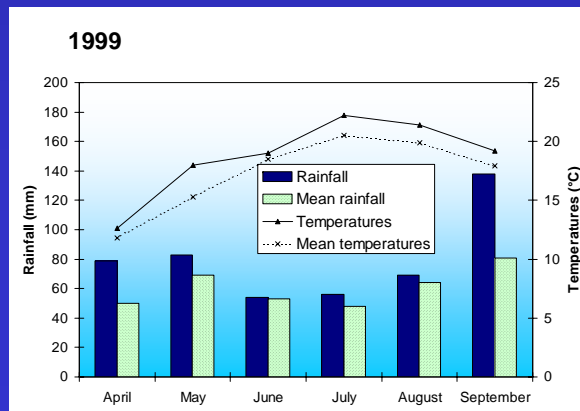
Climate is another important factor in terroir

- Climate varies in space

Sum of active temperatures



- Climate varies in time -> vintage effect



The vine is in interaction with abiotic factors (soil, climate)

- Grapevine variety
- Clone
- Rootstock
- Age



Merlot



Cabernet franc



Cabernet-Sauvignon

Hierarchy of factors in the terroir effect

- Among other factors, **climate, soil and grapevine variety** play a major role in the terroir effect



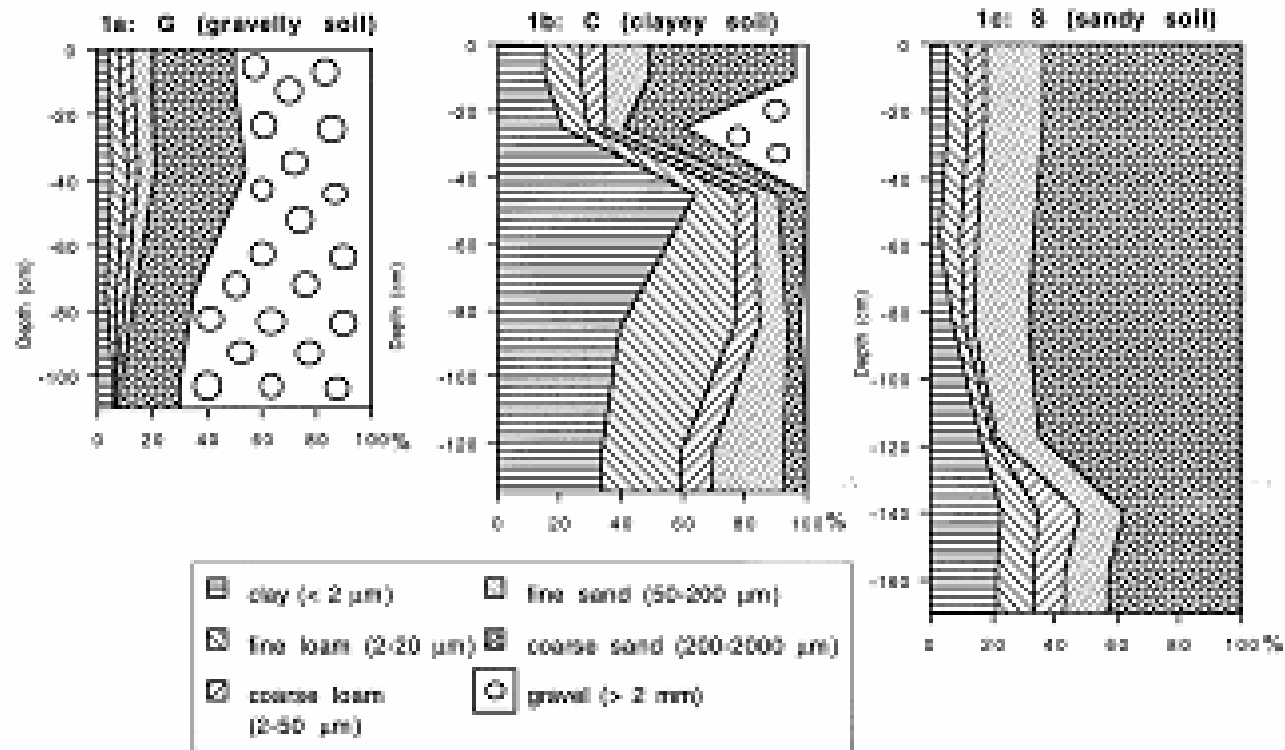
What is the hierarchy between these three factors?

Experimental set-up

- Three red grapevine varieties: Cabernet-Sauvignon, Cabernet franc and Merlot
- Planted on three soils: Sand, Gravel and heavy Clay
- Where studied during eight vintages (variations in climate)
- 37 variables were monitorred
- 3 factor analyses of variance were carried out to compare the role of climate, soil and cultivar in the terroir effect

The soils

Figure 1: Percentage of clay, loam, sand and gravel in the root zone of the gravelly soil (1a: G), the clayey soil (1b: C) and the sandy soil (1c: S).



The climate: eight vintages with specific climatic conditions, from 1996 to 2003

Among these eight vintages every possible combination occurred between wet or dry and warm or cool:

1996: cool and wet

1997: warm and wet

1998: cool and dry

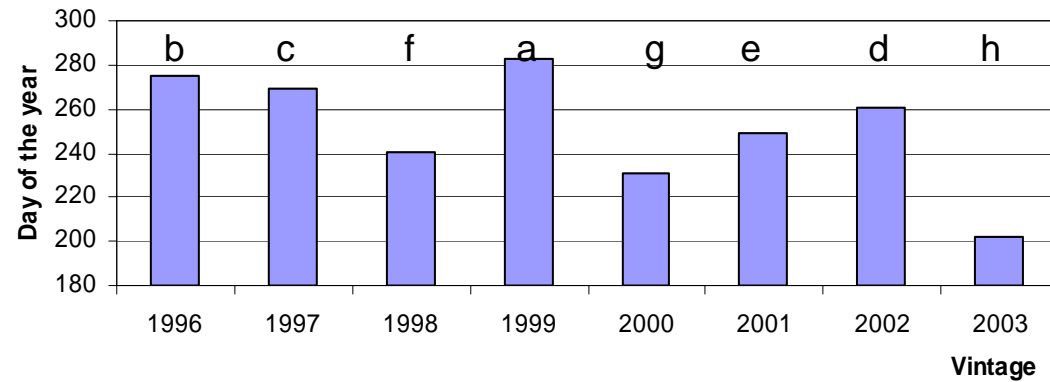
2003: hot and dry

Vine vigor

- One of the variables related to vine vigor is the precociousness of shoot growth cessation
- Delayed shoot growth cessation creates competition between shoot growth and berry ripening

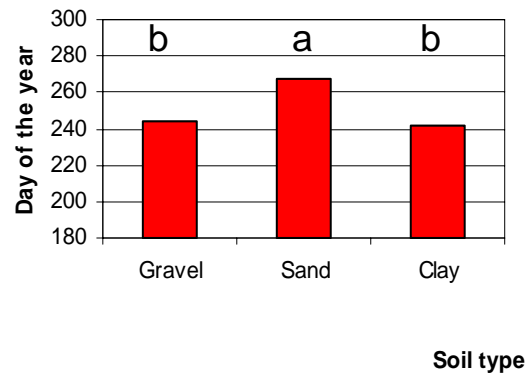
Effect of climate, soil and cultivar on precociousness of growth cessation

Precociousness of growth cessation: vintage effect



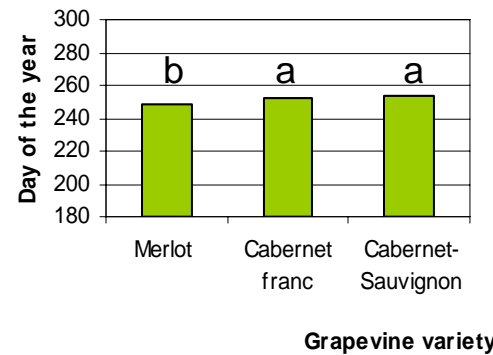
Vintage effect: **75%**
of total variance

Precociousness of growth cessation: soil effect



Soil effect: **15%**
of total variance

Precociousness of growth cessation: cultivar effect

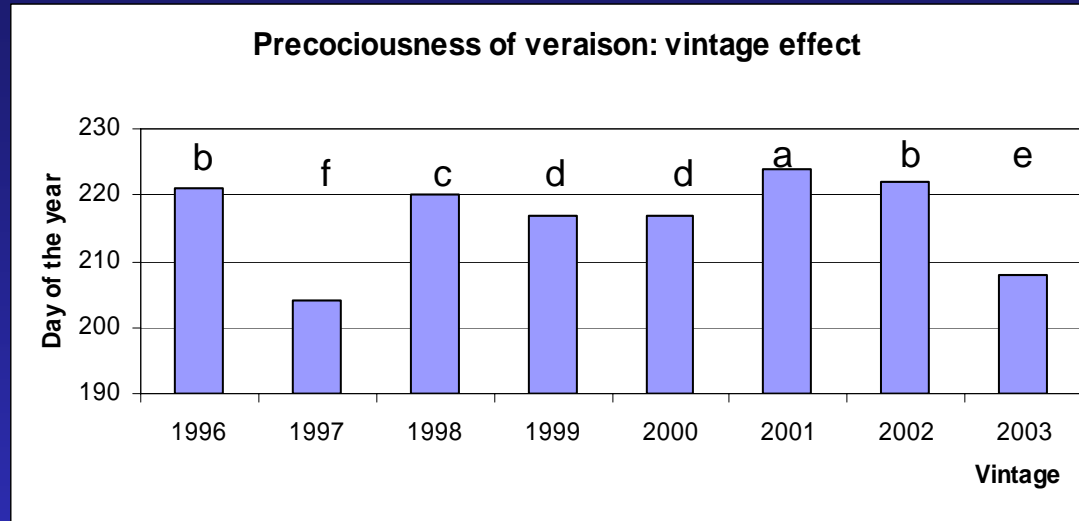


Cultivar effect: **<1%**
of total variance

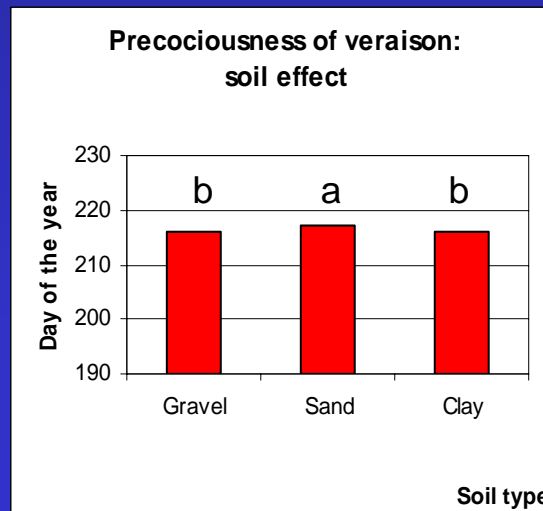
Precociousness of phenological stages

- Depending on climate, soil and cultivar berries can reach ripeness more or less early in the season
- Too late ripening: lack of maturity, green and acid wines
- Too early ripening: wines lacking aroma and « finesse »
- Among phenological stages, veraison is most appropriate to define objectively the precociousness

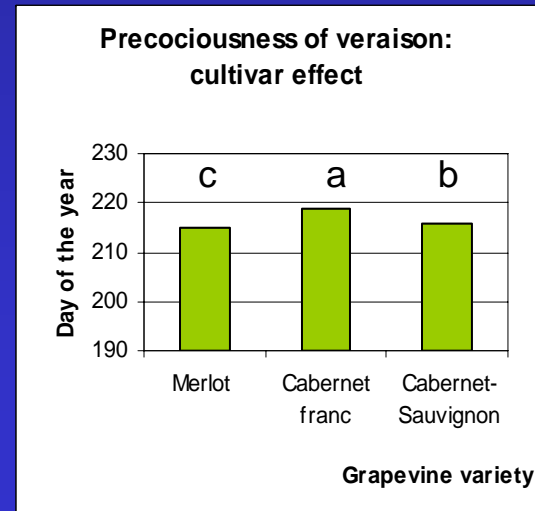
Effect of climate, soil and cultivar on precociousness of veraison



Vintage effect: **88%**
of total variance



Soil effect: **1%**
of total variance

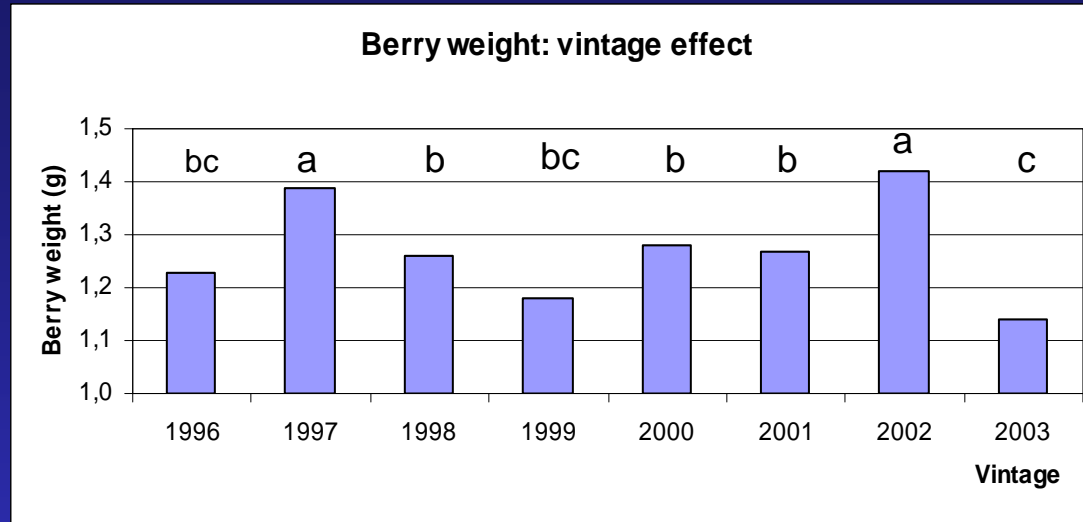


Cultivar effect: **8%**
of total variance

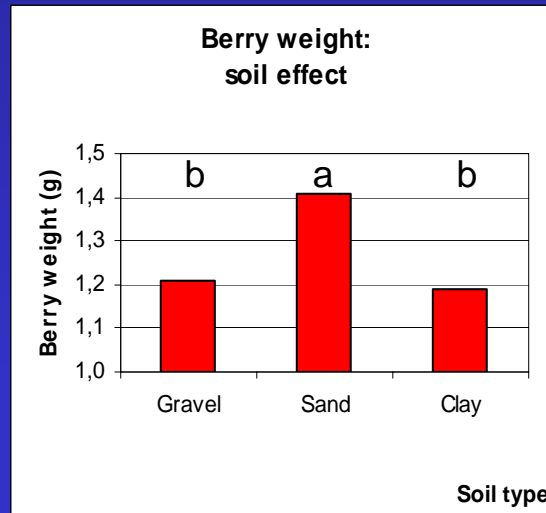
Yield components

- Yield is determined by:
 - Number of vines per hectare (density)
 - Number of shoots per vine
 - Number of clusters per shoot (bud fertility)
 - Number of berries per cluster
 - Berry weight at harvest
- Among yield components, berry weight is also directly related to grape potential:
 - Small berries have higher potential for making quality red wines

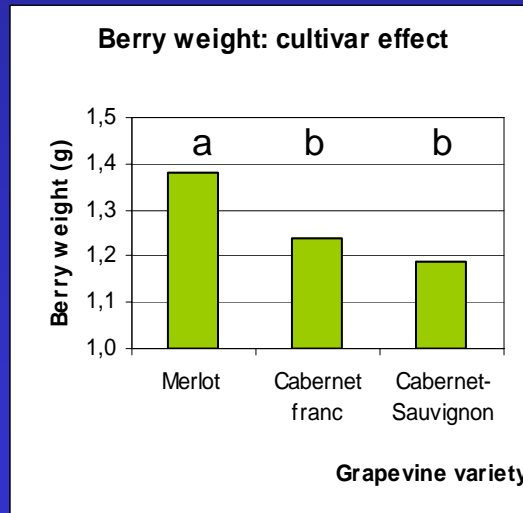
Effect of climate, soil and cultivar on berry weight



Vintage effect: **25%**
of total variance



Soil effect: **32%**
of total variance



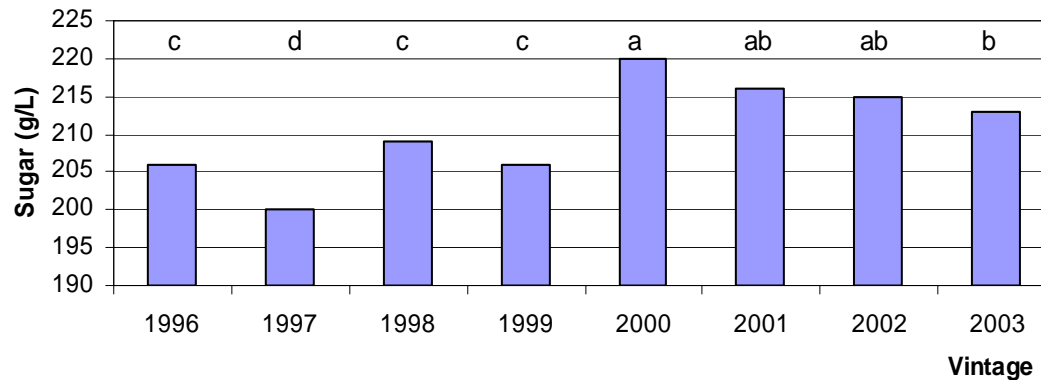
Cultivar effect: **19%**
of total variance

Grape sugar

- Among variables indicating ripeness, grape sugar is most universally used
- However, it cannot be used alone to define grape potential

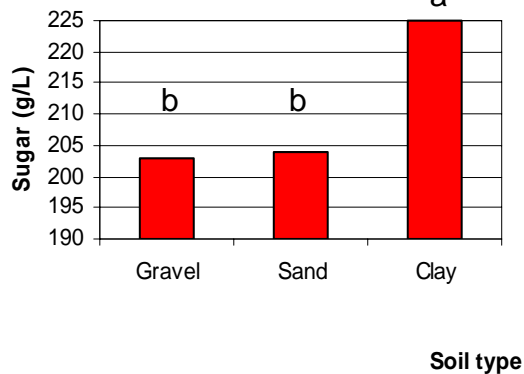
Effect of climate, soil and cultivar on grape sugar content

Grape sugar content at ripeness: vintage effect



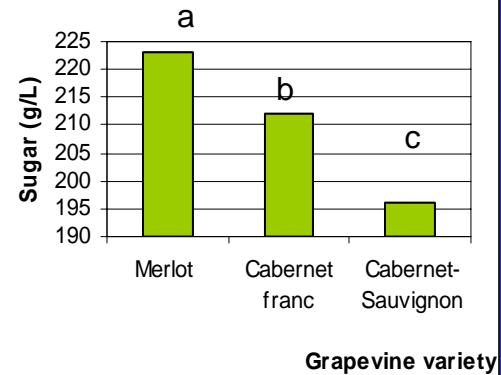
Vintage effect: **13%**
of total variance

Grape sugar content at ripeness: soil effect



Soil effect: **35%**
of total variance

Grape sugar content at ripeness: cultivar effect



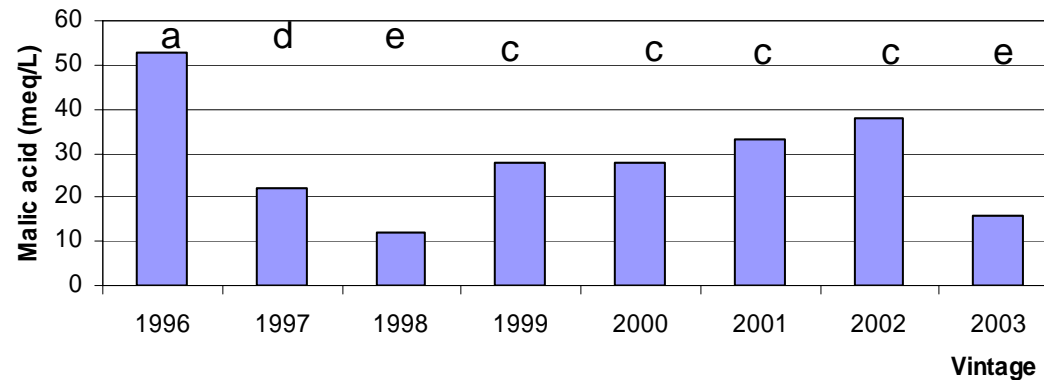
Cultivar effect: **37%**
of total variance

Acidity

- Grape acidity can be expressed by:
 - Total acidity
 - pH
 - Tartaric acid content
 - Malic acid content
- Tartaric acid is the dominant organic acid in grapes, but its level shows little variations
- Malic acid is another important organic acid in grapes; its level is highly variable
- -> Variations in grape acidity are generally well correlated with variations in grape malic acid content

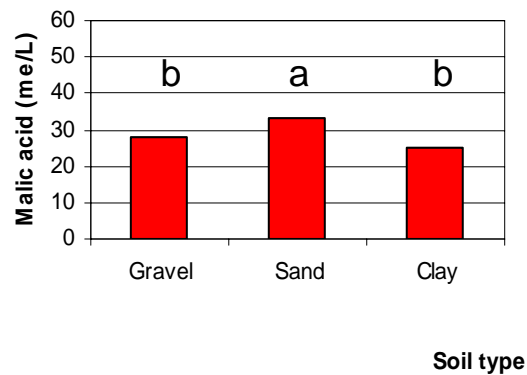
Effect of climate, soil and cultivar on grape malic acid content

Malic acid content at ripeness: vintage effect



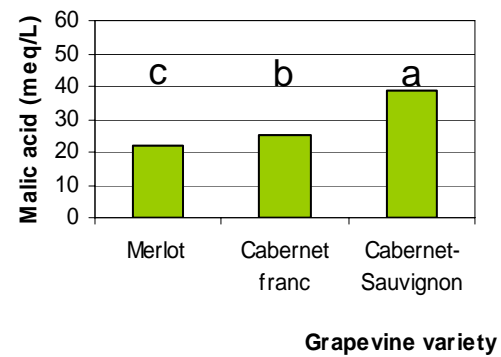
Vintage effect: **60%**
of total variance

Malic acid content at ripeness: soil effect



Soil effect: **5%**
of total variance

Malic acid content at ripeness: cultivar effect



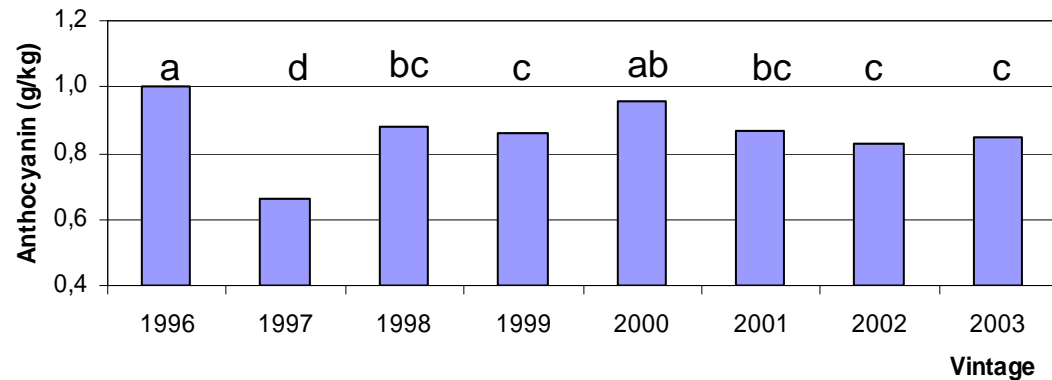
Cultivar effect: **21%**
of total variance

Skin phenolic content

- Red wine quality is highly dependant on the abundance of grape skin phenolics
- Anthocyanin content is highly correlated to tannin content
- Anthocyanin measurements are more reproductable than tannin measurements

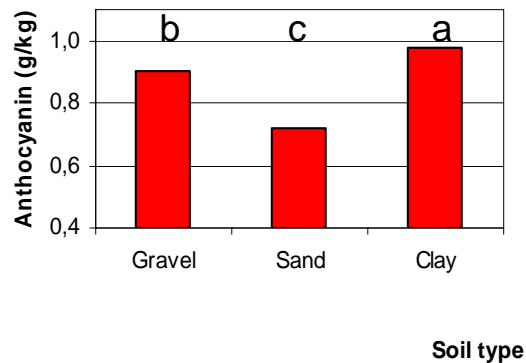
Effect of climate, soil and cultivar on grape anthocyanin content

Anthocyanin content at ripeness: vintage effect



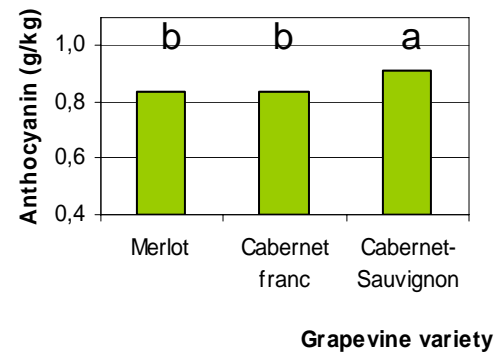
Vintage effect: **31%**
of total variance

Anthocyanin content at ripeness: soil effect



Soil effect: **39%**
of total variance

Anthocyanin content at ripeness: cultivar effect

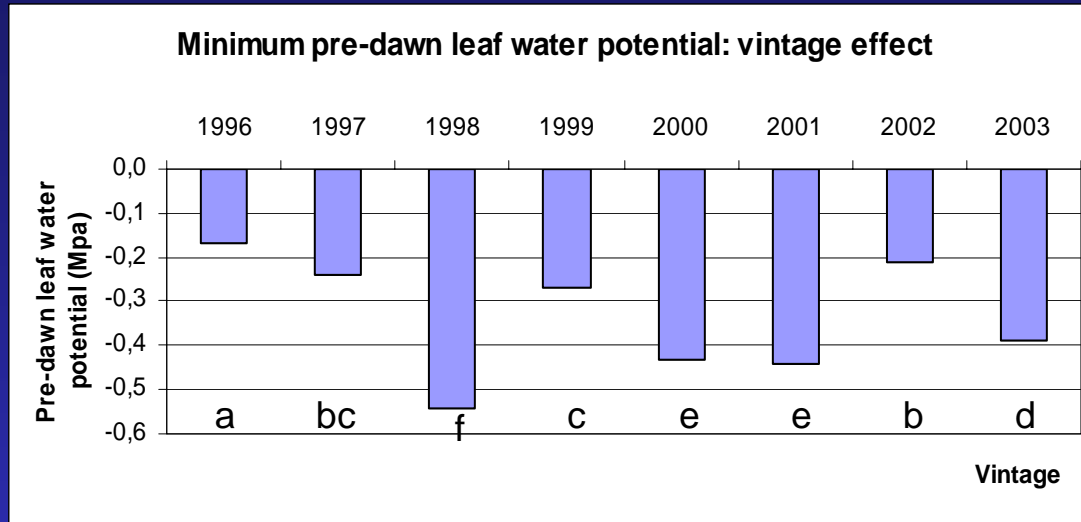


Cultivar effect: **4%**
of total variance

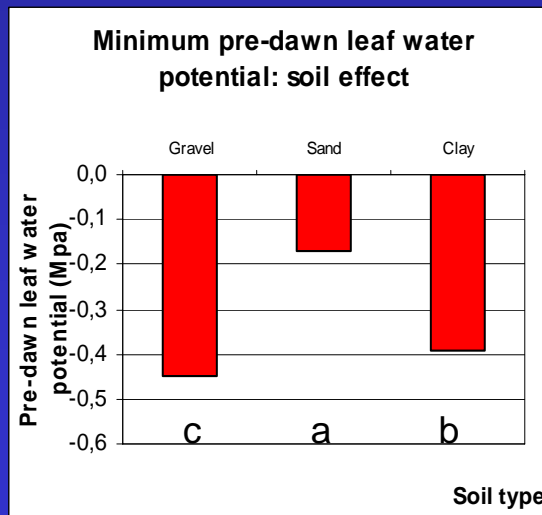
Vine water status

- Climate and soil act on vine water status
- Vine water status can be assessed by measuring leaf or stem water potential
- The more negative the values, the more the vine are subject to water deficit

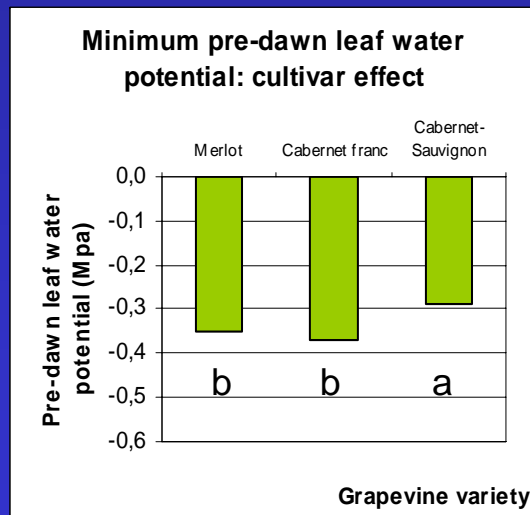
Effect of climate, soil and cultivar on minimum pre-dawn leaf water potential



Vintage effect: **42%** of total variance



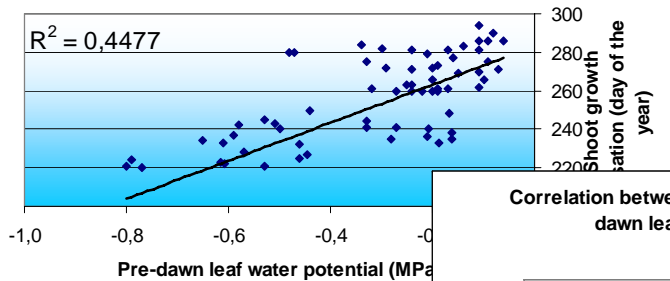
Soil effect: **39%** of total variance



Cultivar effect: **3%** of total variance

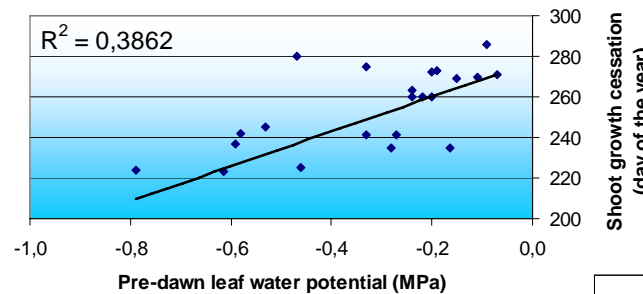
Correlation between vine water status and precociousness of shoot growth cessation

Correlation between shoot growth cessation and minimum pre-dawn leaf water potential (Merlot, Cabernet franc, Cabernet-Sauvignon, 1996-2003)



3 cultivars, 8 vintages

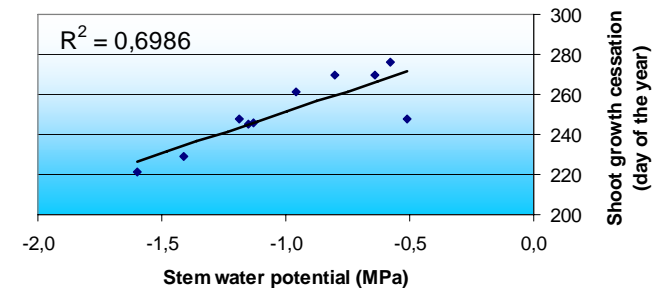
Correlation between shoot growth cessation and minimum pre-dawn leaf water potential (Merlot, 1996-2003)



1 cultivar, 8 vintages

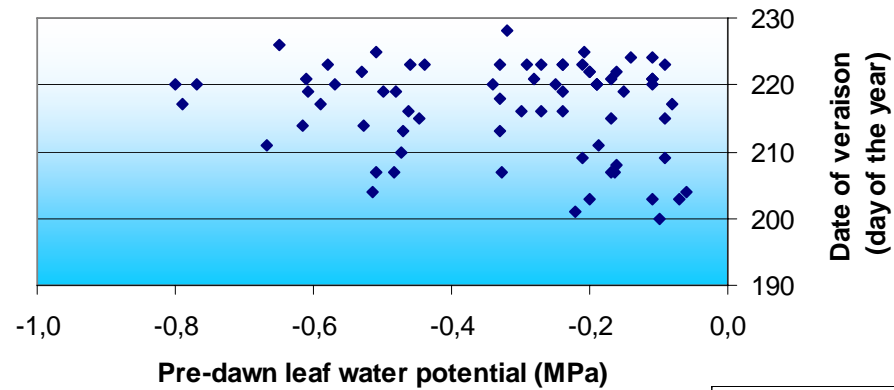
1 cultivar, 1 vintage

Correlation between shoot growth cessation and minimum stem water potential (Merlot, 2000)



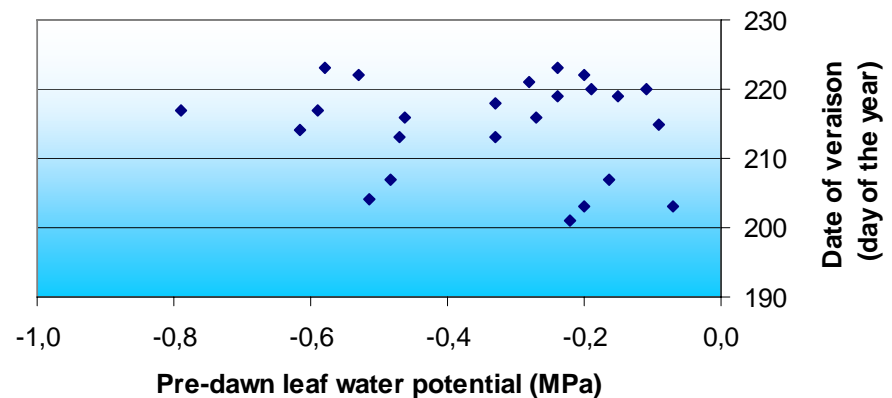
Correlation between vine water status and precociousness of veraison

Correlation between precociousness of veraison and minimum pre-dawn leaf water potential (Merlot, Cabernet franc, Cabernet-Sauvignon, 1996-2003)



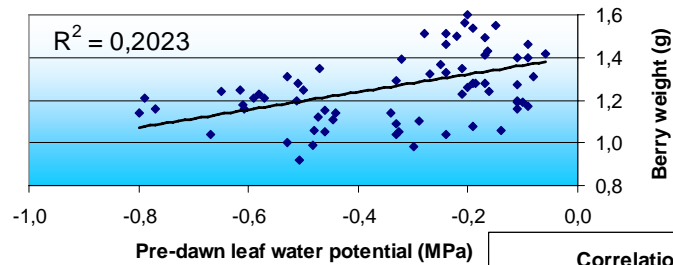
1 cultivar, 8 vintages

Correlation between precociousness of veraison and minimum pre-dawn leaf water potential (Merlot, 1996-2003)



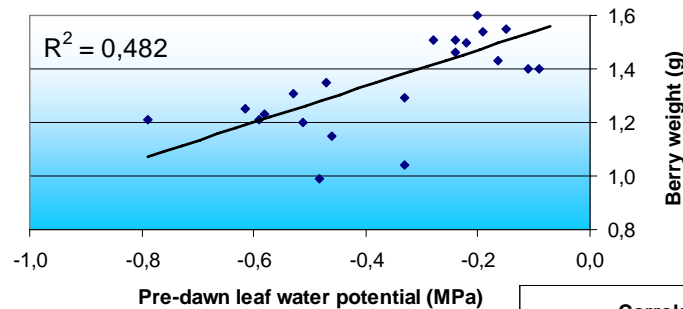
Correlation between vine water status and berry weight

Correlation between berry weight and minimum pre-dawn leaf water potential (Merlot, Cabernet franc, Cabernet-Sauvignon 1996-2003)



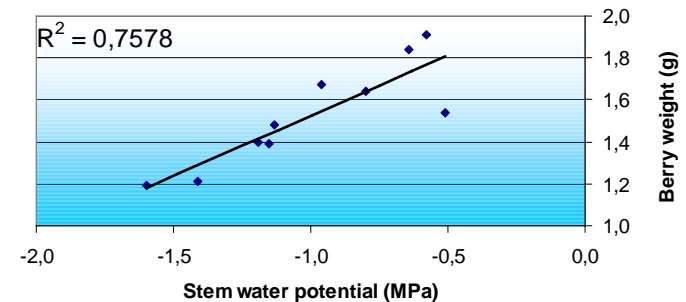
3 cultivars, 8 vintages

Correlation between berry weight and minimum pre-dawn leaf water potential (Merlot, 1996-2003)



1 cultivar, 8 vintages

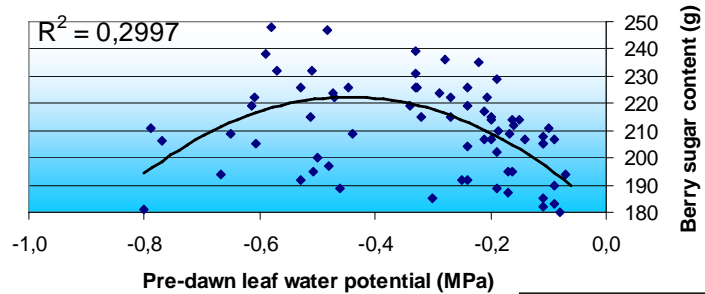
Correlation between berry weight and minimum stem water potential (Merlot, 2000)



1 cultivar, 1 vintage

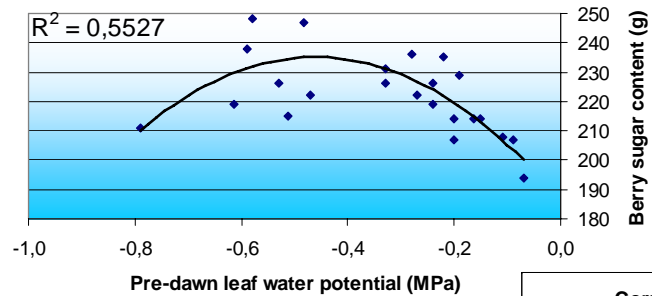
Correlation between vine water status and grape sugar content

Correlation between berry sugar content and minimum pre-dawn leaf water potential (Merlot, Cabernet franc, Cabernet-Sauvignon, 1996-2003)



3 cultivars, 8 vintages

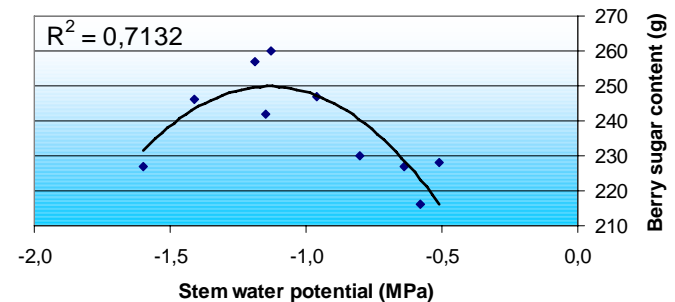
Correlation between berry sugar content and minimum pre-dawn leaf water potential (Merlot, 1996-2003)



1 cultivar, 8 vintages

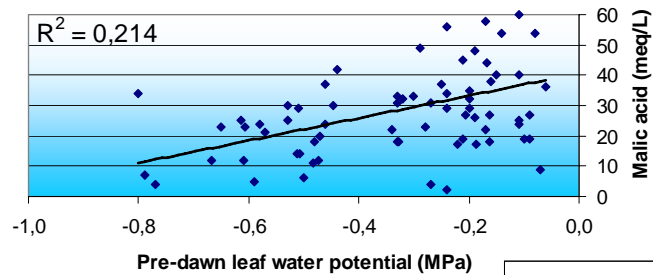
1 cultivar, 1 vintage

Correlation between berry sugar content and minimum stem water potential (Merlot, 2000)



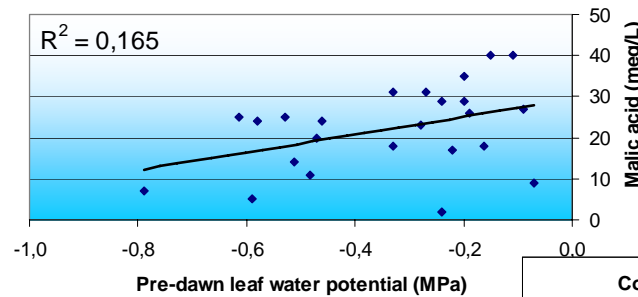
Correlation between vine water status and grape malic acid content

Correlation between berry malic acid content and minimum pre-dawn leaf water potential (Merlot, Cabernet franc, Cabernet-Sauvignon, 1996-2003)



3 cultivars, 8 vintages

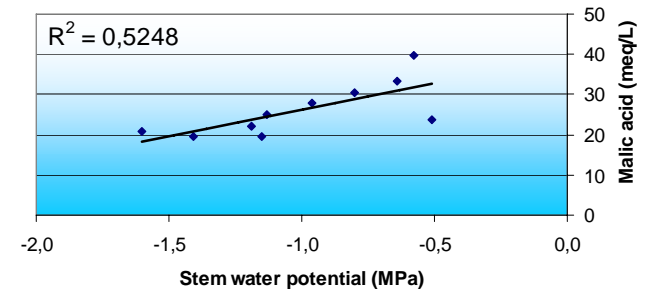
Correlation between berry malic acid content and minimum pre-dawn leaf water potential (Merlot, 1996-2003)



1 cultivar, 8 vintages

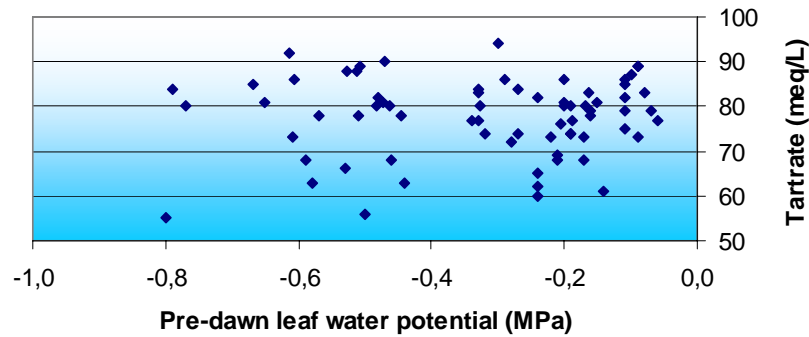
1 cultivar, 1 vintage

Correlation between berry malic acid content and minimum stem water potential (Merlot, 2000)



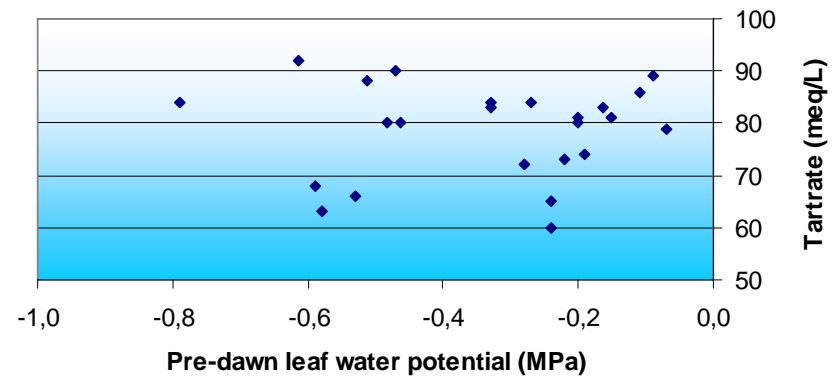
Correlation between vine water status and grape tartaric acid content

Correlation between berry tartrate content and minimum pre-dawn leaf water potential (Merlot, Cabernet franc, Cabernet-Sauvignon, 1996-2003)



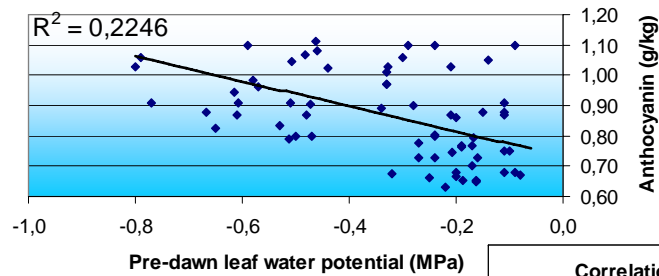
1 cultivar, 8 vintages

Correlation between berry tartrate content and minimum pre-dawn leaf water potential (Merlot, 1996-2003)



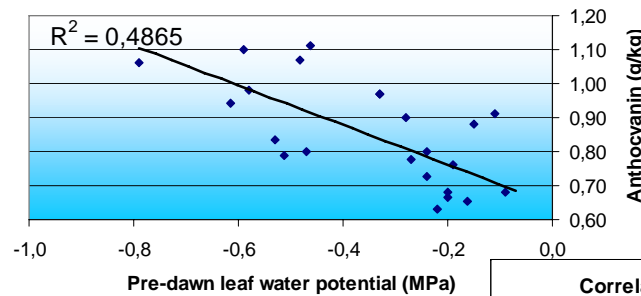
Correlation between vine water status and grape anthocyanin content

Correlation between berry anthocyanin content and minimum pre-dawn leaf water potential (Merlot, Cabernet-franc, Cabernet-Sauvignon, 1996-2003)



3 cultivars, 8 vintages

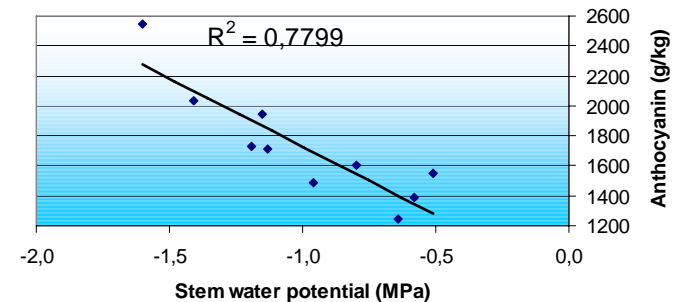
Correlation between berry anthocyanin content and minimum pre-dawn leaf water potential (Merlot, 1996-2003)



1 cultivar, 8 vintages

1 cultivar, 1 vintage

Correlation between berry anthocyanin content and minimum stem water potential (Merlot, 2000)



Conclusion

- On most of the variables, the effect of climate > soil > cultivar
- Terroir effect is largely mediated through vine water status, which depends on climate (rainfall, ET_0) and soil (water holding capacity)
- Shoot growth and berry size are reduced in water stressed vines
- Malic acid is reduced and anthocyanin is increased in water stressed vines
- Grape sugar content is optimum when water deficit is mild
- Precociousness of veraison and tartaric acid are not related to vine water status