# INFLUENCE OF SOIL TYPE ON JUICE QUALITY IN A VINEYARD FROM DO CA RIOJA

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## ABSTRACT

Soil plays an important role in wine quality, especially its water holding capacity because it affects the balance between vigour and grape yield. The aim of this work was to study the influence of different soil types on the must quality in a vineyard at DO Ca Rioja. The study was carried out during 2006 and 2007 in a vineyard of eight hectares, located in Oyón in Northern Spain. Four soil types were established according to topography and parent material: deposition (deeper than 110 cm and irregular distribution of organic matter in depth), calcareous red argillite (depth of 85-100 cm, with a heavy clay layer with reddish colour at 85-100 cm), calcareous lutite (depth of 50-100 cm) and finally sandstone (depth of 25-80 cm, and high sand content in depth). Grape samples were collected at 190 grapevines distributed through the whole vineyard for analysing , potential alcohol, total tartaric acid, pH, and K, and anthocyanins concentrations and polyphenols and colour indexes. The influence of soil type on juice quality varied according to the year. In 2006, in the soils with the lower water content (Sandstones) the potential alcohol was the highest (12.92 º), while in 2007, the Red argillite soil (greater water availability) got the greatest potential alcohol (13.72 º). The highest acidity was obtained in Depression soil (5.51 g $L^{-1}$) and was higher in 2007 (5.48 g $L^{-1}$) than in 2006 (5.07 g $L^{-1}$). Potassium juice concentration (3068 mg L-1) was higher in the Red argillite soil type due to its higher soil K content, and this caused also the higher pH (3.48) shown in this soil. The anthocyanins content, and polyphenols and colour indexes reached higher values in the Sandstone soil (803 mg $L^{-1}$, 64 and 24 respectively).

## KEY-WORDS
Terroir, Potential alcohol, poliphenols, colour index, anthocyanins, acidity

## INTRODUCTION
The aim of modern winemaking is to produce wines of high quality and tipicity that can compete in an increasingly broad and competitive market (Ubalde et al., 2007). This quality is closely related to the specific soil, climate, agronomical practices and training system conditions, which in turn are related to the cultivar. The concept of "terroir" is often used to describe this relationship (Deloire et al., 2004) and is usually defined as the ecosystem interaction taking place in a given area, including climate, soil, variety and vineyard management (Seguin, 1988). Thus, soil plays an important role in wine quality, especially its physical properties such as drainage, depth and texture which derive in a good soil water holding capacity. Soil water content is a main factor for the development of vineyards and wine composition. Increased water availability can increase yield (Williams and Matthews, 1990), while it is considered that a moderate stress as a result of reduced water availability

improves quality. The reduced vegetation caused by the hydric stress results in a better bunch exposure to light and also in a smaller fruit size which end in an improvement of the grape quality (McCarthy et al., 2000).
The objective of this work was to study the influence of the soil type on the juice quality in a vineyard from DO Ca Rioja.

## MATERIAL AND METHODS

The study was conducted during 2006 and 2007 on an eight hectare vineyard called "Costanillas", owned by Zuazo Gastón Winery. The vineyard was located in Oyón (Northern Spain) in the Denominación de Origen Calificada (DO Ca) Rioja, and the vines were " Tempranillo" (*Vitis Vinifera* L.) trained in a double cordon system. The soil surface is periodically cultivated to limit weed growth. The soil of the vineyard is calcareous (average carbonate content of 155 g $kg^{-1}$ from 0 to 30 cm), with a high pH (8.6). Four soil types were identified thanks to a soil survey based on the description and analysis of 12 soil pits and 27 soil observations made by a hand auger. The soils were classified according to their depth, texture, organic matter vertical distribution and parent material: 1 - Depression: Soil depth greater than 110 cm, with a clay content of 250-310 g $kg^{-1}$ at 70-100 cm. The main feature of this soil is the irregular distribution of organic matter in depth, the content drops at 62-100 cm, and increases again from this depth. This change in the downward trend is due to the erosion processes occurring in the vineyard, since this land is located in a low area where two slopes converge and the eroded soil from both of them accumulates there.
2 – Calcareous red argillite: Soil with a depth of 85-100 cm and a layer of calcareous argillites at 60-74 cm depth. This layer is characterized by a high clay content (450-500 g $kg^{-1}$) and soil K (72-76 mg $kg^{-1}$ ) and Mg (2,7-4,1 mg $kg^{-1}$) contents higher than in the other soil types at the same depth.
3 – Calcareous lutite. Soil depth of 50-100 cm, and clay content in depth of 270-380 g $kg^{-1}$.
4 - Sandstone. Soil depth is between 25 and 80 cm. It is characterized by a high sand content in depth (about 300 g kg-$^{1}$) and the lower clay content of the vineyard (230 g $kg^{-1}$). Climatology. The average annual rainfall was 399 mm and average temperature 13.5 º C according to the meteorological station Agoncillo, close to the plot. The climatic conditions of the years 2006 and 2007 are shown in Table 1. The plot has a drip irrigation system with emitters with a flow of 2.5 L $h^{-1}$ and a distance between emitters of 0.7 m. In the year 2006 the vineyard was watered and in 2007, irrigation was applied at 29 and 30 July with a total dose of 57 mm. A sampling mesh of 24x14.4 m was designed, marking 190 vines. Grape samples were taken from these vines to measure the following quality parameters:
- Quality parameters related to the pulp. The yield of each vine was squeezed and afterwards analyzed. Potential alcohol (PA) was measured with a refractometer, total tartaric acidity and pH by automatic potentiometry.
- Juice properties related to the skin. The yield of each vine was weighted and small fragments of every harvested bunch were taken. These fragments were cut at the top, middle and bottom of the bunch. Then all the berries were separated and 100 of them were weighted, and another 200 were separated and blended in a Mixer for two minutes obtaining a slurry. Potassium and anthocyanin concentration, and polyphenols and colour indexes were measured in this slurry. Potassium was measured by flame atomic absorption, the colour index by spectrophotometry (420 +520 +620 nm), the total polyphenol index by spectrophotometry at 280 nm and anthocyanins using the method of bleaching with sodium bisulfite (quote).

Statistical analysis. Difference in quality properties caused by soil types and years were studied using the analysis of variance, and mean separation was made by Duncan's test. SAS Statistical program was used (SAS, 1998).

**RESULTS AND DISCUSSION**

A significant interaction was observed between "year" and "soil type" and therefore the behaviour of the potential alcohol was studied within each soil type and for each of the years (Tab. 2). Based on the behaviour of the potential alcohol in the different soil types in the two years two groups were made, which mainly differ in soil water holding capacity. On the one hand the Depression and Red argillite soils, with a high water holding capacity and on the other side Sandstone and Calcareous lutite soils with lower water retention capacity. In 2006, the Sandstone and Calcareous lutite soils presented the highest potential alcohol (12.92 ° and 12.88 °, respectively) (Tab. 2), while in 2007 the opposite occurred, i.e. Red argillite and Depression soils showed the highest PA. These results are related to the rainfall distribution in the two study years. In 2006, heavy rainfall occurred in the early stages of development of the berries, and exceeded in 54 mm the historical average, while the period from veraison to maturity was characterized by being drier (41 mm less rainfall). The synthesis and accumulation of sugars are higher when water availability is low from bloom to veraison (Rhul and Alleweldt, 1985; Rhul, 1988) and there is high water availability during maturation (Smart et al., 1974, Hardie and Considine 1976; Rühl and Allewedt, 1985, García-Escudero 1991, 1994 and Gutierrez-Granda Sipiora 1998, Esteban et al., 1999; Intrigiololo and Castel 2010). In this way we can explain the different behaviour of the potential alcohol  Sn the different soil types each year. In 2006, excessive water availability from bloom to veraison prevailed over the relatively dry maturation period. So the soils with lower water retention capacity (Sandstone and Calcareous lutite) showed the higher PA In 2007 the rainfall was high during maturation, therefore the soils with the greater soil water holding capacity (Red argillite and Depression) obtained the highest PA in their musts. Studying the reasons for the favourable or unfavourable effect of soil water at different times of the growing cycle, Van Zyl (1985) and Rhul (1988) suggested that high water availability in the period between bloom and veraison causes an excessive vegetation, which decreased the light received by the bunches. This induces a delay in the maturation so the desired sugar content is not reached at the time of harvest. Regarding the effect of water availability in maturation García-Escudero (1991), Esteban et al., (1999) and Deloire et al., (2004) argue that the plant activity is adversely affected by water deficit in maturation, which results in a decrease in the potential alcohol, because the plant is not able to meet the needs of sugar accumulation by the reduction of photosynthetic activity. Furthermore, Smart et al., (1974), Hardie and Considine (1976), Neja et al. (1977) and Bravdo (1984) note that a severe water deficit in the maturation period is related to an inadequate maturation. Coipel et al. (2006) conducted a study in 15 vineyards located at west of the river Rhone (France) and within “Appelation controllee” Côtes du Rhône (France). Five soil types were established primarily by soil depth, identifying deep soils (deeper than one meter), and shallow soils with a depth of 60 to 80 cm. They found that soil water availability was inversely related to the sugar content of the grapes, with shallower soils showing higher sugar contents. In our case, however, the behaviour of the sugar content in the different soil types depends on the climatic conditions of the year, more precisely the distribution of rainfall plus irrigation.

Generally the PA was higher in 2007 except in Sandstone soils, probably because in this year the water availability was higher in the period of maturation, promoting the synthesis and accumulation of sugars.

Significant differences were observed for juice total acidity between different soil types and different years of study (Tab. 3), but no interaction was detected between the two factors. Depression soils showed about 0.5 g $L^{-1}$ higher total tartaric acidity, compared to the other soils. This difference is mainly due to vines vigour in this soil that induces on one hand a certain delay in the maturation process, and on the other hand, an increase in the shading of the bunches. This is the result of enlarged vegetative mass, which has a positive influence on the total acidity (García-Escudero, 1991). Kliever and Schultz (1964) observed that the greater shading of bunches in vineyards with irrigation, as a result of intense vegetative growth, gives juices with higher acidity, since acid degradation by combustion is lower. Similarly, in 2007 the acidity was higher respect to 2006 and that is probably due to a difference in the vine vigour as in the case of the differences between soil types. Regarding the pH, the only difference was observed in the Red argillite soil in the year 2007, which had a pH significantly higher than the other soils (Tab. 2). The juice K concentration in this type of soil, as shown below, is higher due to higher soil K content. There is a clear relationship between K and pH of the juice, since high levels of K cause the precipitation of tartaric acid to potassium bitartrate (Mpelasoka et al., 2003). Consequently, there is a decrease of tartaric acid levels and in turn an increase in pH (Boulton 1980, Gawel et al., 2000), because this acid is among the organic acids, which exerts more force on the pH. Significant differences were found between the years of study and the soil types regarding to juice K, anthocyanin concentrations and polyphenol and colour indexes, but the interaction was not significant. Usually the same trend was observed for all these properties related to the berry skin, being the highest values at the Sandstone soil(Tab. 3). The only exception was the juice K concentration, which was higher on the Red argillite soil. The higher soil K content in this soil at 60-75 cm had more influence on juice K concentration than other soil properties. Sandstone soils had the lowest water holding capacity due to the shallower depth and the coarser texture. So we could say that low water availability has led to an improvement of the berry skin related properties. These results are consistent with several research studies (Van Leeuwen et al., 2004; Coipel et al., 2006), whose authors argue that the soils with lower soil water holding capacity are the ones which produces better colour properties in the must. The influence of water on these parameters , is related to the influence on the vine vigour, linked with more vegetative growth and therefore a lower lightening of the bunch, which disfavours the synthesis of polyphenols and anthocyanins. Besides, soil water content in the first stages of growth (until approximately mid-July) has a strong influence on berry size (Hardie and Considine, 1976; Matthews and Anderson, 1988;, Jackson and Lombard, 1993; Esteban et al., 1999; Roby et al., 2004; Ollat et al., 2002), with higher berry weight when water availability is greater. The bigger the berry size, the lower the ratio skin:pulp and therefore the concentration of the parameters commented. However, in our case there was not a clear influence of soil type on berry weight (Tab. 2). This is probably due to the difficulty of sampling correctly, and we hypothesize that perhaps the way of taking the sample was not sufficiently representative to reflect differences between different soil types. Subsamples of each vine should have been taken to assess the accuracy of the measurement.
In 2007 must K, anthocyanins, and polyphenols concentrations and colour index were higher than in 2006 (Tab. 3). These differences can be related to the difference in berry weight (Tab. 2) found. Berry weight was generally higher in 2006 than in 2007 due to the rainfall from bloom to veraison in 2006, which, clearly has a positive influence on the berry weight. These results agree with Garcia-Escudero (1991), Esteban et al., (1999) Intrigliolo et al., (2010), who found a negative relationship between berry size and must colour, related to the irrigation

provided in the first growth phase of the berry called herbaceous growth. The water availability at this period increases the berry size, decreasing the ratio skin:pulp.

## CONCLUSIONS

Soil variability caused by different parent materials and erosive processes in a vineyard influences the qualitative properties of the must.

The effects of climate and soil type on the must quality are largely explained by the relationship they have to soil water content. Interaction between soil type and year is observed sometimes, which means that properties such as the potential alcohol behave differently in different soil types under different climatic conditions. The qualitative properties related to the skin such as must anthocyanins, polyphenol and colour indexes, showed the highest values in the soils with the lower water retention capacity (Sandstone soils). Soils with higher soil K content (Calcareous red argillite soils) showed higher juice K concentration.

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**Table 1.** Precipitation collected at the meteorological station of Agoncillo at different times of the cycle, for the years 2006 and 2007 and the historical mean (years from 1973 to 2007), together with the irrigation applied.

| Rainfall (mm) | 2006 | 2007 | Historical mean |
|---|---|---|---|
| Budbreak-Bloom | 90 | 125 | 88 |
| Bloom-Veraison | 131 | 85 | 77 |
| Veraison-Harvest | 50 | 43+*57* | 91 |
| Growing cycle | 270 | 254 | 221 |

Budbreak-Bloom = 1st April-31st May; Bloom-Veraison: 1st June – 31st July; Veraison-Harvest- 1st August- 12th October; Growing cycle; 1st April- 12th October. Figures in italics are the irrigation dose for each period.

**Table 2** Year and soil type based means for potential alcohol, pH and berry weight.

| | Potencial alcohol (%) | | | pH | | | Berry weight (g) | | |
|---|---|---|---|---|---|---|---|---|---|
| | 2006 | 2007 | Prob. | 2006 | 2007 | Prob. | 2006 | 2007 | Prob. |
| Sandston | 12,92 a A | 12,81 a B | *** | 3,45 a A | 3,48 a B | * | 2,42 a A | 1,91 b A | *** |
| Red argilite | 12,01 a B | 13,72 a A | *** | 3,50 a A | 3,58 a A | * | 2,02 a B | 2,10 a A | n.s. |
| Depression | 12,45 b AB | 13,16 a AB | *** | 3,45 a A | 3,46 a B | * | 2,39 a A | 2,06 b A | *** |
| Calcareous lutite | 12,88 b A | 13,45 a AB | *** | 3,49 a A | 3,49 a B | * | 2,47 a A | 2,05 b A | *** |
| Prob. | * | * | | *** | *** | | * | n.se. | |

*** Prob.<0.001; ** Prob.<0.01, * Prob.<0.10. Means with the same capital letter refers to differences inside the same column and means with the same small letters to differences inside a row.

**Table 3.** Year based and soil type based means for total acidity, K, anthocyanins, poliphenols index, colour index and pruning weight.

| | Año | | | Suelo | | | | |
|---|---|---|---|---|---|---|---|---|
| | 2006 | 2007 | Prob | Sandstone | Red Argillite | Depression | Calcareous lutite | Prob |
| Total acidity acidity (g $L^{-1}$) | 5,07b | 5,48a | *** | 5,09b | 5,07b | 5,51a | 5,14a | *** |
| K (mg $l^{-1}$), | 2495b | 2765a | *** | 2762b | 3068a | 2484c | 2717bc | *** |
| Anthocyanins (mg $l^{-1}$), | 643b | 720a | * | 803a | 729ab | 734ab | 734ab | *** |
| Poliphenols index | 50b | 56a | *** | 64a | 55b | 49b | 49b | *** |
| Colour index | 18b | 21a | *** | 24a | 20b | 18b | 18b | *** |
| Pruning weight (kg $vine^{-1}$). | | | | 0,56c | 0,76b | 0,88a | 0,68bc | *** |

*** Prob.<0.001; ** Prob.<0.01, * Prob.<0.10.