Using ΔC13 to assess viticultural and oenological suitability for Sangiovese of different pedoclimatic conditions in Chianti.

Le ΔC13 pour établir l'aptitude viticole et oenologique du Sangiovese dans différentes conditions pédoclimatiques du Chianti.

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Summary

A two years trial was carried out in Chianti (Central Italy) to assess at the detailed scale the viticultural and oenological suitability for Sangiovese of different pedoclimatic conditions, by means of the ΔC13 measured in the must sugars. Six plots placed in two specialised vineyards in similar geomorphological conditions were investigated. The plots differed for morphological position: summit, backslope and footslope. The soils of the vineyards were similar, except for structure, porosity and related hydropedological characteristics. Soil water content and temperature were measured at different depths. Measurements were replicated every one/two weeks. Soil characterization included macroporosity quantification by image analysis.
The yield, phenological phases, and chemical analysis of grapes were determined. The isotopic ratio $^{13}C/^{12}C$ was measured in the must sugar upon harvesting. Grapes of each plot were collected for wine making in small barrels. The wines obtained were analysed and submitted to a blind organoleptic testing.
The results demonstrated that almost all plots had rather high amounts of transpirable water, even during the driest time of the year; however, the response of Sangiovese was influenced by site hydropedology. The soils in morphological positions receiving and holding more water produced significant worst results in the moister 2005, than during the drier 2006. The drier soils yielded the best results in both years, but more prominently in 2005. Vines of the plots having a lower soil water availability produced relatively higher values of ΔC13, as well as a better oenological and organoleptic result. The ΔC13 test confirmed the limited stress conditions in the two vineyards, despite yields in the two years ranged from 2 to 8 kg per plant. This result highlighted the pedoclimatic limitations of the studied sites in obtaining high quality wine.

Key words: carbon isotopes, hydropedology, porosity, land evaluation, terroir.

Introduction

In the Mediterranean environment, characterized by a summer water deficit, the phenology and production potential of cultivations are significantly determined by soil water availability. Also the vegetative and reproductive activity of the grapevine, which renews a good part of its absorption system each year, is deeply influenced by the rate of water available during the year. Besides the amount of rain, soil water availability is conditioned by water holding capacity, which in turns is regulated by soil texture and structure, rooting depth, and topography, which can convoy rain water and subsurface flows to different places of the vineyard.
Recently, besides yield components, oenological parameters and sensorial evaluation, a new physiologic indicator has been used for describing the vineyard water regime during the ripening period, that is the ratio between the two stable carbon isotopes $^{13}C/^{12}C$, called ΔC13, measured in the must sugars upon harvesting. The indicator could also be used to assess local suitability conditions for vines, like Sangiovese, which need a moderate water stress during summer, to produce high quality

wine. Aim of this work was to investigate the possibility of using ΔC13 to assess at the very detailed scale the influence of pedoclimatic conditions on grape yield and wine quality of Sangiovese vine.

Materials and methods

Two specialised vineyards (2 ha each) were investigated at Cetona (Chianti area, central Italy), in similar geomorphological settings. The soil of vineyard 1 is a Stagnic Cambisols (Endosodic, Calcaric), while the soil of vineyard 2 is a Stagnic Cambisols (Calcaric) according to WRB (F.A.O. et al., 2006). The experimental soils lay on slopes and host a perched water table during rainy seasons. Hydropedological properties of soils at summit (position S, slope 2%), backslope (position B slope 13 and 18% vineyards 1 and 2, respectively) and footslope (position F slope 2 and 5% vineyards 1 and 2, respectively) were characterised by profiles and mini-pits, as well as with a 2 year monitoring of soil water content and temperature. Soil water content was measured by the gravimetric method (three samplings with a hand auger) at 0.1-0.3 m and 0.4-0.7 m depth and soil temperature at 0.2 and 0.5 m depth (portable pt100). Measurements were replicated every one/two weeks. An index of soil temperature efficiency was calculated from the 1st of April until the 15th of September. The cumulative active soil temperature at 0.2 and 0.5 m was obtained from the difference between the measured soil temperature and 8°C, negative values being excluded. Bulk density and water saturation were calculated from the field measured value of humidity when soil was saturated, moisture content at field capacity was obtained from field core sampling a week after soil was saturated, wilting point was the minimum soil water content obtained during the field core sampling. Moisture content at field capacity (-33 kPa) and wilting point (-1500 kPa) were also analysed in laboratory by ceramic-plate system (Kassel and Nielsen, 1986) and bulk density with the core method, on replicated samples. Saturated hydraulic conductivity was estimated according to Rosetta (Schaap, 2001). In-field cone resistance was measured by a hand-held electronic cone penetrometer (Eijkelkamp Penetrologger 06.15.SA) following ASAE standard procedures (1994), using a cone with 2 cm^2 base area, a 60° included angle and a 80-cm driving shaft; readings were recorded at 10 mm intervals. Nine replicated measurements were carried out in each position along the slope. Soil characterization included macroporosity quantification by image analysis. Three thin sections of undisturbed samples for soil horizon were analyzed to quantify pores >50 µm (Vignozzi et al., 2007). Two images were captured with a video camera from each section. Total porosity and pore distribution were measured according to pore shape and size. Pore shape was expressed as perimeter 2/(4π area), and pores were divided into regular (shape factor 1-2), irregular (2-5) and elongated pores (>5). Pores of each shape group were further subdivided into size classes according to either the equivalent pore diameter for regular and irregular pores, or to the width for elongated pores (Pagliai, 1988). During the years 2005 and 2006, three replicated sampling per plot were conducted onto ten plants of the cultivar Sangiovese. The vegetative behaviour of the plants was examined, in particular the evolution of phenological phases, the characteristics of the production, the chemical analysis of the grapes and the isotopic ratio $^{13}C/^{12}C$ measured in the must sugar upon harvesting. Hundred kg of grapes of each plot were collected for wine making in small barrels, following a standardized technique. The wines obtained were analysed with particular attention to colour density and phenolics content. Ten months later the wines were submitted to a blind organoleptic testing with the aim of defining a rank of preferences in terms of general harmony.

Vineyard position and depth (cm)	Clay	Sand	Consistence*	Structure^	Cone index (Pa)	Redox mottles (%)	Roots ($n.dm^{-2}$)	Bulk density† ($g.cm^{-3}$)	Saturation†	FC§	WP¶	Ksat‡ ($cm.h^{-1}$)
	($g.kg^{-1}$)								(% v/v)			
1A 0-15	350	110	FR	SB	453	2	4	1.59	40.0	36.0	15.1	0.109
1A 15-60	357	59	RE	AB	1435	20	5	1.60	39.6	38.0	16.9	0.083
1B 0-15	393	35	FR	SB	616	2	1	1.53	42.3	32.8	14.4	0.203
1B 15-50	334	8	RE	AB	1476	15	2	1.58	40.4	33.7	16.0	0.159
1C 0-10	380	3	FR	SB	236	3	0	1.56	41.3	38.1	16.6	0.102
1C 10-45	229	52	FR	AB	1032	50	3	1.58	40.4	38.8	16.6	0.139
2A 0-15	223	108	FR	SB	315	2	2	n.d.	n.d.	n.d.	n.d.	0.331
2A 15-35	242	79	FR	SB	668	15	2	1.52	42.6	35.5	13.9	0.351
2A 35-65	242	103	FR	SB	1072	20	2	1.53	42.3	33.9	14.4	0.370
2B 0-15	225	170	FR	SB	371	0	3	1.49	43.8	36.0	15.1	0.472
2B 15-65	217	46	FR	SB	773	10	3	1.50	43.4	34.5	17.1	0.206
2C 0-15	290	196	FR	SB	443	8	2	1.49	43.8	37.4	15.3	0.182
2C 15-65	324	1	FR	SB	952	8	3	1.51	43.0	37.8	17.0	0.109

Table 1 Plot main pedological characteristics
* Consistence moist: FR=friable, RE=resistant
^ Structure: SB =subangular blocky. AB=angular blocky
† Calculated from the field measured value of humidity when soil was saturated
§ Field capacity: soil water content obtained from field core sampling a week after soil was saturated
¶ Wilting point: minimum soil water content obtained from field core sampling
‡ Saturated hydraulic conductivity according to Rosetta (Schapp, 2001)

The isotopic ratio $^{13}C/^{12}C$ was measured by Isotope Mass Spectrometry and the ΔC13 was expressed in reference to the international standard V-PDB (Farquhar et al, 1989; Van Leeuwen et al., 2001). It is generally assumed that the range of values varies for vine between -21‰, in the case of strong water deficit stress, and -26‰ or more in total absence of stress (Van Leeuwen et al., 2003)

Results and discussion

Mean soil characteristics of the three morphological positions in the two vineyards are reported in table 1.

The studied soils are rather clayey and poor in sand. Structure, penetrometry and hydrological parameters contrast notably in the profile and between plots, however, they all show evidences of seasonal waterlogging (redox mottles) and have a limited root density. The tendency to host a perched water table is confirmed by the low soil macroporosity that affects all the plots, although with variations between vineyards (fig. 1); vineyard 2 is relatively more porous and better structured than vineyard 1.

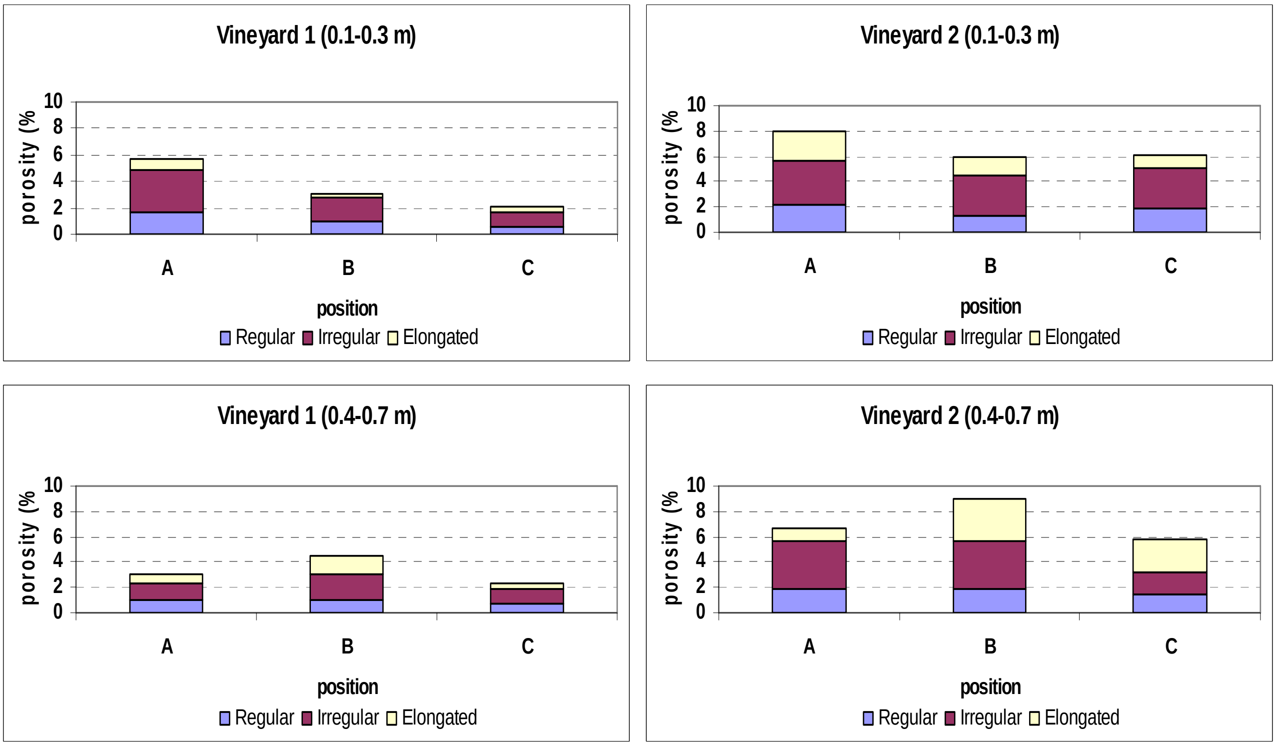


Figure 1 Soil macroporosity in the three morphological positions of the two studied vineyards.

During the trial, the year 2005 was more humid and chilly than normal, whereas 2006 was relatively drier (fig. 2).

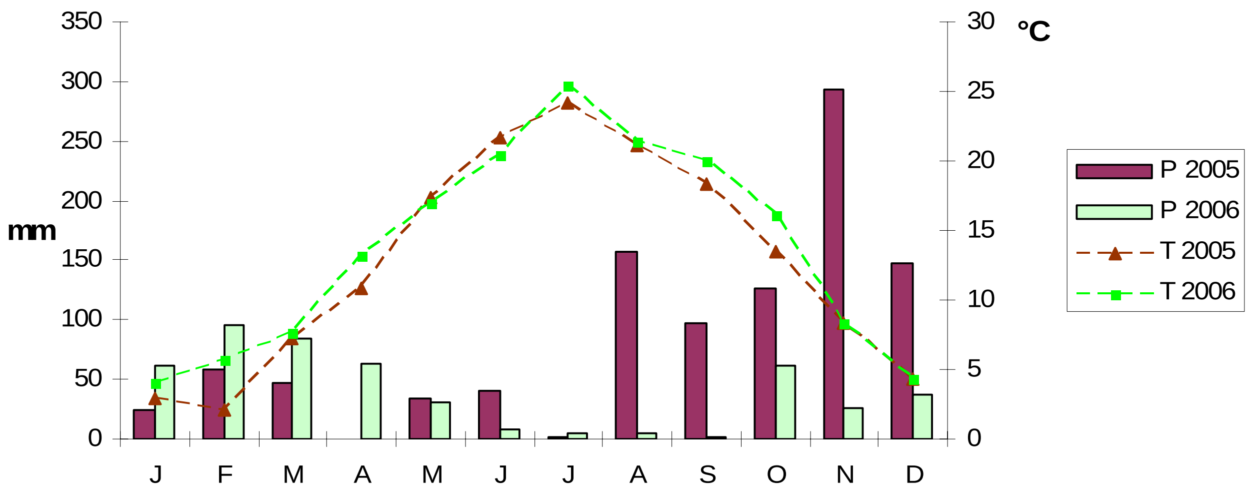


Figure 2 Precipitation and air temperature during the study period

Available soil water in the different plots is reported in table 2. As a whole, transpirable soil water was enough to fulfil the need of the plant even during the driest time of the season. The effects of years and morphological position were highly significant, while the mean available soil water was not different between vineyards.

Vineyard, position and depth (cm)	Year 2005	Year 2006
1A 10-30	6.18	2.00
1A 40-70	4.07	2.31
1B 10-30	4.21	2.40
1B 40-70	4.36	3.01
1C 10-30	6.31	3.07
1C 40-70	7.15	5.47
2A 10-30	2.15	1.49
2A 40-70	2.37	3.24
2B 10-30	3.40	2.25
2B 40-70	2.29	2.41
2C 10-30	9.42	2.71
2C 40-70	9.78	2.22
Mean	5.14 A	2.71 B
Vineyard 1	4.21 ns	
Vineyard 2	3.64 ns	
Position S	2.97 B	
Position B	3.04 B	
Position F	5.77 A	

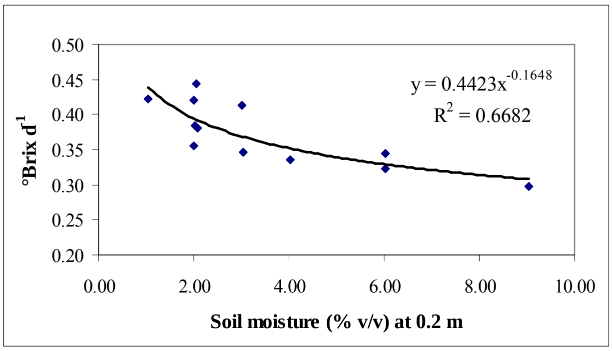
Table 2 Mean daily transpirable soil water (mm) from the 6th of July to the 15th of September. Variables with capital letter differ significantly for P<0.01

Vineyard, position and depth (cm)	Year 2005	Year 2006
1A 20	2344	2574
1A 50	2215	2289
1B 20	2325	2404
1B 50	2082	2212
1C 20	2320	2296
1C 50	2125	2209
2A 20	2122	2304
2A 50	1999	2217
2B 20	2019	2136
2B 50	1819	2069
2C 20	2041	2093
2C 50	1844	1973
Mean	2097 ns	2214 ns
Vineyard 1	2283 A	
Vineyard 2	2053 B	
Position S	2258 ns	
Position B	2133 ns	
Position F	2112 ns	

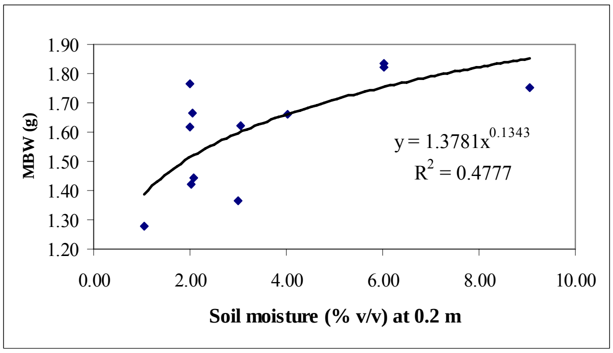
Table 3 Cumulative active soil temperature at 0.2 and 0.5 m (soil temperature -8°C, negative values excluded) from the 1st of April until the 15th of September. Variables with capital letter differ significantly for P<0.01.

Nevertheless, the statistical analysis (HSD test of Tukey) showed that there was a significant interaction effect between vineyard, position and year. In particular, footslope positions had more water in both vineyards during the moister 2005, summit and backslope resulted poorer in available water, during both years, particularly in vineyard 2.

In spite of the different rainfall, soil temperature was not significantly different in the two years (tab. 3). Also the different morphological position did not highlight an effect on soil temperature. On the other hand, the effect of vineyard was highly significant, probably because of the different soil structure, porosity and length of the period with soil moisture conditions were at or near saturation.
From the chemical-analytical results of vinifications, we can deduce that wines of the soil having a lower water availability were qualitatively superior in colour and structure (the highest level of colour density and total polyphenols) in both years, but mainly in 2006. In a similar way, the organoleptic analyses of both vintages gave the best results in the soil receiving and holding a lesser amount of water.



a)



b)

Figure 2 Correlation between soil moisture at 0.2 m depth from the 6th of July to the 15th of September and °Brix d^{-1}(a) $P<0.01$; and Mean Berry Weight (MBW) (b) $P< 0.05$.

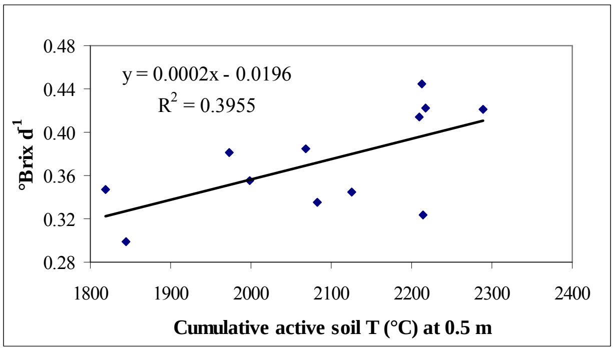
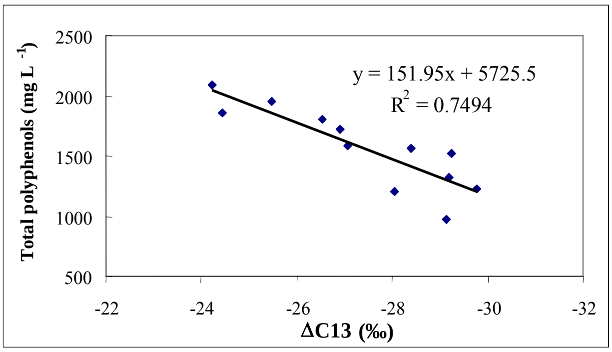
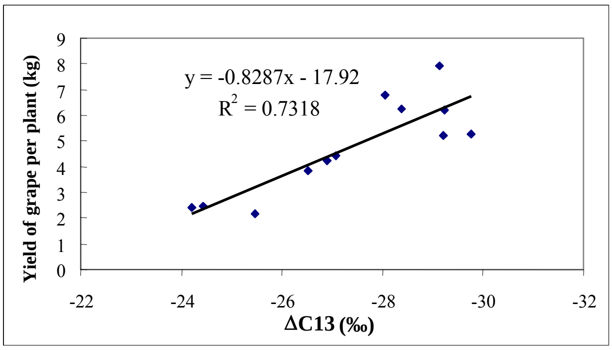


Figure 3 Correlation between cumulative active soil temperature at 0.5 m depth and °Brix d^{-1}; $P< 0.05$.

It is interesting to note the potential and inverse relationship between soil moisture at 20 cm and both sugar accumulation and mean berry weight (fig. 2), as well as the linear relationship between sugar accumulation rate and soil temperature (fig. 3). These trends indicate that water stress was in most cases too low to induce a high sugar accumulation rate and to reduce the weight of berries, which are related to good oenological results. The linear influence of soil temperature on sugar accumulation, on the other hand, stresses the importance of the different drainage conditions in the plots, that is, the higher and more prolonged the soil water content, the lower the active soil temperature.
The correlation between ΔC13 and some analytical parameters of grapes and wines gave significant results for yield of grape per plant (fig. 4b), sugar content, total acidity of must, wine colour density, total anthocyanins and polyphenols in wines (fig 4a). The relation between ΔC13 and yield per plant was very significant (R^2=0.732) and confirmed that the pedoclimatic characteristics of Cetona do not provide severe water stress conditions, even in case of limited yield per plant. On the other hand, only when grape production is reduced, total polyphenols of wines reach interesting values for Sangiovese quality.



a)



b)

Figure 4 Correlation between ΔC13 and wine total polyphenols (a) $P < 0.01$; and yield of grape per plant (b) $P < 0.01$.

Conclusions

The trial demonstrated that the response of Sangiovese vine was influenced by site hydropedology, which varied according to both soil type and topographic position. The interaction with the climate of the year was evidenced in both vintage. Almost all plots had rather high amounts of transpirable water, even during the driest time of the year. The soils in morphological positions receiving and holding more water produced significant worst results in the moister 2005, than during the drier 2006. The soils receiving and holding a lesser amount of water yielded the best results in both years, but more prominently in 2005. Vines of the plots having a lower soil water availability produced relatively higher values of ΔC13, as well as a better oenological and organoleptic result. The influence of hydric conditions were both direct and indirect. The viticultural and oenological results were affected by both the amount of transpirable water during the driest time of the year, and the active soil temperature, which in turn was influenced by water content.
The ΔC13 test confirmed the absence of stress in vineyard 2 and the moderate stress in vineyard 1, but only in 2006, despite yields in the two years ranged from 2 to 8 kg per plant. This result summaries the pedoclimatic limitations of the studied sites in obtaining high quality wine.

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