The performance of grapevines on identified terroirs in Stellenbosch, South Africa

Comportement de la vigne sur les différents terroirs identifiés à Stellenbosch, Afrique du Sud

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Abstract

A terroir can be defined as a natural unit that is characterised by a specific agricultural potential, which is imparted by natural environmental features, and is reflected in the characteristics of the final product. Preliminary terroirs were defined for Stellenbosch for Sauvignon blanc and Cabernet Sauvignon using decision trees built on analyses of viticultural, oenological and environmental data measured on a network of plots over 7 seasons. This study was considered to be a preliminary approach to determine the validity of terroir studies for the South African wine industry.

It was expected that measurement of viticultural and oenological variables would serve to validate or refine the decision trees constructed with the first set of data and that the measurement of ecophysiological parameters on a separate network of reference plots would facilitate improved understanding of the grapevine x terroir interaction. Three plots of 10 vines each were therefore identified in selected commercial vineyards of Cabernet Sauvignon and Sauvignon blanc using remote sensing as a tool to identify homogenous plots where possible. These vineyards were representative of dominant terroir units that were identified for each cultivar. This network of experimental plots was monitored with respect to their ecophysiological response to the growing environment. This included dynamics of canopy development, vegetative growth, dynamics of berry growth and composition and wine character. Pre-dawn leaf water potential was determined at different stages during the growth season. The growing environment was characterised with respect to soil and climate by means of direct observations and measurements and interpolated values from the agroclimatic weather station network.

This paper will examine the results from three seasons for selected Sauvignon blanc and Cabernet Sauvignon vineyards from this network and compare these results to previous findings.

Key-words: Sauvignon blanc, Cabernet Sauvignon, soil, ecophysiology, Stellenbosch

Introduction

Research into the delimitation of viticultural terroirs in South Africa forms a research programme of Winetech (Wine Industry Network for Technology and Expertise). A preliminary study to investigate the validity of the terroir concept in South Africa and to determine a possible methodology for the identification of terroir units was completed in 2005. In order to determine the functioning of the grapevine and the characteristics of the final product on a particular natural terroir unit , it is necessary to perform *in situ* studies resulting in point data. In order for this information to be of use within zoning studies, it must be placed within the context of the pertinent terroir in order to provide a spatial result (Vaudour 2000; 2001). An environmental model to identify terroirs, therefore, consists of various logical arguments and processing methods. The first stage of the preliminary study consisted of an empirical (i.e. deterministic) inductive model (Skidmore 2002). Field data was explored for possible patterns that could be used to derive a general statement with respect to viticultural or oenological performance using the classification and regression tree methodology (CART) (Breiman et al. 1984). These results were used to derive thresholds that could be used in empirical models. The second stage encompassed a knowledge-driven deductive model. The rules generated from the statistical induction phase were used to summarise relationships between dependent and environmental variables. These rules were used to directly classify unknown spatial objects by deduction (Skidmore 2002). From the results of this study it would seem that environmental parameters have an overriding effect on the performance of both Cabernet Sauvignon and Sauvignon blanc in Stellenbosch, despite heterogeneous vineyard management, but that these two cultivars react differently to environmental stimuli.

The data generated from the network of experimental plots used in the above mentioned study were based on measurements that were easily performed, as this was a preliminary approach. Thus, although rationale for observed relationships of measured viticultural and oenological variables with site related environmental variables could be proposed, it was not possible to state with any certainty the reasons for a particular response. The measurement of ecophysiological parameters on reference plots (grapevine water balance, canopy development, dynamics of berry ripening, organic acid ratios, etc.) was expected to facilitate improved understanding of the grapevine x terroir interaction. Measurement of viticultural and oenological variables on an alternative network of plots was also expected to serve to validate or refine the decision trees constructed with the first set of data.

Materials and methods

The two cultivars under investigation are Cabernet Sauvignon and Sauvignon blanc, situated in the Stellenbosch Wine of Origin District. Experimental plots have been laid out in commercial vineyards at ca. 15 localities per cultivar. Each vineyard has three mini-plots of 10 vines each marked out in areas of similar growth vigour as determined by means of multispectral imagery during January 2004. If it was not possible to obtain a multispectral image of the vineyard due to vineyard location and/or management practices, the three plots were laid out diagonally across the vineyard and excluded gross visually determined vigour differences. Plots were selected from amongst an initial pool of ca. 30 vineyards per cultivar based on the homogeneity of response between the three mini-plots during the 2004/2005 season, accessibility and degree of representation of major identified terroir units. From amongst this network 2 Sauvignon blanc and 2 Cabernet Sauvignon vineyards, representing different but significant terroirs have been selected for comparison in this paper (Table 1).

Name	Co-ordinates	Altitude	Aspect	Slope	Irrigation	Rootstock	Plant year
Sw SB	33°51.865 S 18°46.887 E	155 m	358	4%	Drip	Richter 99	1990
Sw CS	33°51.857 S 18°46.881 E	159 m	293	3%	Drip	Richter 99	1991
Ru SB	33° 52' 55.4 S 18° 53' 59.5 E	476 m	170	17%	Drip	Richter 99	1990
Ru CS	33° 53'26.8 S 18°54'22.3 E	387 m	222	10%	Drip	Richter 99	1990

Table 1 Details of Sauvignon blanc and Cabernet Sauvignon plots, Stellenbosch.

Soil and root profiles

Soil profiles at each plot were examined in 2000 and described using the South African taxonomic system (Group 1991). Standard soil chemical and physical analyses were performed in a commercial laboratory. The root systems were described using the profile wall method of Böhm (Böhm 1979) on a grid of 10 x 10cm during July and August 2007 and classified into categories based on their diameter (< 0,2 mm ; 0,2 - 2 mm ; 2 - 5 mm; 5 - 7 mm; > 7 mm). The total number of roots in each category per 10 cm depth was calculated, as well as the ratio of (<2 mm: >2 mm).

Grapevine vegetative growth

Six shoots were sampled at per vineyard at 5 phenological stages (ca. one month after budburst, full bloom, pea-size, véraison and berries harvest-ripe). Primary shoot length, leaf area of the primary shoots, lateral shoot length and lateral shoot leaf area were determined per shoot. The cane mass per meter cordon was determined at pruning.

Grapevine physiological measurements

Pre-dawn leaf water potential was determined at similar times to the canopy measurements. Juice samples were analysed in the Stable Light Isotope Laboratory, UCT, by combustion in a Thermo 1112 Elemental Analyser coupled via a Thermo Conflo III to a Thermo Delta XP stable light isotope mass spectrometer. Samples were run against in-house reference materials and the results were normalised against, and reported relative to, the international standards (PDB for carbon) to determine C_{12} and C_{13} isotope ratios.

Yield and berry composition

The yield per meter cordon was determined at harvest. Berry samples were taken according to the method of Iland (Iland et al. 2000) at four stages (bunch closure, véraison, intermediate brix values and at berries harvest-ripe). Organic acids were determined by means of enzymatic (Malic acid - L-MalicEnzymatic BioAnalysis Kit) and colorimetric (Tartaric acid - ISITEC-LCAI L'INSTRUMENTATION ACTIVE) kits. Inorganic K^+ elements were determined at a commercial laboratory on separate samples of flesh and skin of 50 berries following dry-ashing of the plant material. The total anthocyanin and phenol content of a sample of 50 berries were determined by spectrophotometer readings at 700 nm, 520 nm and 280 nm after extraction with ethanol (Iland et al. 2000).

Microvinification

The grapes from the mini-plots were harvested at harvest-ripeness, combined and micro-vinified according to standard Department of Viticulture and Oenology guidelines. Sensory analyses of the wines was performed ca. 9 months after harvest using a generic descriptive analysis and an unstructured line scale.

Statictic

Statistica 8 (StatSoft.Co. Inc) was used to perform one-way or repeated measures ANOVA, depending on the variable being evaluated. The Fischer LSD test was used to test for significance between means.

Results and Discussion

The selected plots RuCS, RuSB, SwCS and SwSB were considered to represent previously determined terroir units, for which a specific grapevine response and winestyle could be predicted (Tables 2 and 3). For Sauvignon blanc, the terroir units were based largely on climatic variables, while soil related factors played a more important role for Cabernet Sauvignon terroirs.

Vineyard	Terroir	Harvest	Yield	Yield:pruning mass ratio	Capacity	Fresh veg.	Dried veg.	Tropical fruit
RuSB	27	~11-Mar	~2.7 kg/m	~3.9	>1.0 kg/m cordon	~3.6	~0.8	~1.6
SwSB	37	~23-Feb	~1.5 kg/m	~5.6	~0.7 kg/m cordon	~3.6	~1.5	~2.7

Table 2 Predicted response of two Sauvignon blanc vineyards for selected variables based on previously identified terroir units.

Terroir	Terroir	Berry	Floral	Fullness	Must composition	Yield
RuCS	34	~3.3	~0.3	~5.6	Must TTA ~ 8.9 g/L Must pH ~ 3.2 Maturity Index ~ 25	< 1.8 kg
SwCS	17	~3.9	~0.6	~5.1	Must TTA ~ 7.5 g/L Must pH ~ 3.5 Maturity Index ~ 31	1.1-1.8 kg depending on clone

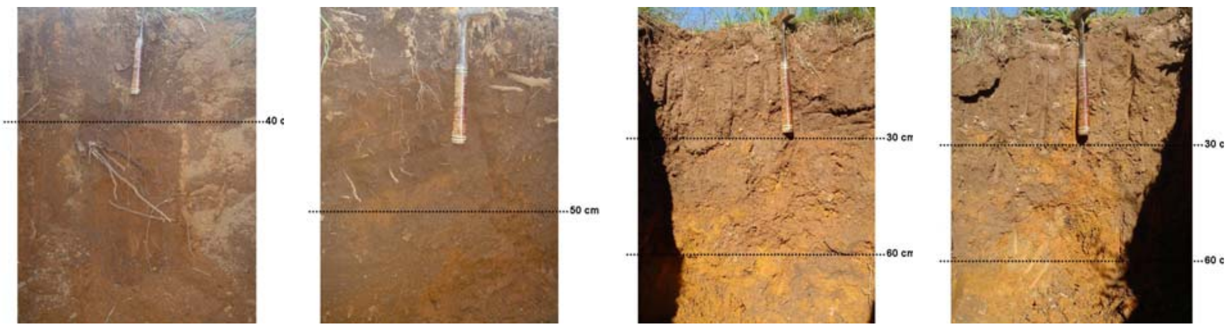
Table 3 Predicted response of two Cabernet Sauvignon vineyards for selected variables based on previously identified terroir units.

The soils at RuCS and RuSB (Fig. 1 and 2) were typical of the highly weathered, reddish to yellowish brown, acid, granitic soils that are common in this area. These soils typically have a low base, status, are stable and prone to compaction of the subsoil and are well-drained but have a good soil water holding capacity. The soils at SwCS and SwSB (Fig. 1 and 2) were, on the other hand, typical of the duplex soils, consisting of sand on clay. These soils can result in extremes of wetness and drought. Comparison of the root profiles shows significant differences as regards the mean number of fine roots (<0.5 mm) in the soil profile as well as the ratio of fine:thick roots (Table 4). The duplex soils at SwCS and SwSB can be said to have stimulated a more optimal ratio of fine:thick roots (Archer and Hunter 2005) across the soil profile. Examination of the differences per depth (data not shown) shows that the RuCS and RuSB soils have most of their roots distributed between 20 cm and 50 cm depth, thus the A horizon, while roots occur mostly between 50 cm and 80 cm in the SwCS and SwSB soils, probably in the transitional layer created as a result of top soil being mixed, or "inserted" with the clay subsoil during soil preparation.

Vineyard	<0.2 mm	0.2-2.0 mm	2.0-5.0 mm	5.0-7.0 mm	>7.0 mm	Ratio (<2.0 mm: >2.0 mm)	Total number of roots	Total number of roots per profile
RuCS	1.4 ^{a}	6.9 ^{a}	13.3 ^{a}	0.7	0.6	0.9 ^{a}	22	229
RuSB	8.9 ^{b}	14.3 ^{b}	11.4 ^{a}	0.5	0.5	1.8 ^{ab}	35	357
SwCS	0.7 ^{a}	16.5 ^{b}	6.6 ^{b}	0.4	0.4	3.1 ^{c}	25	246
SwSB	0 ^{a}	18.7 ^{b}	7.1 ^{b}	0.4	0.7	2.7 ^{b}	27	269
***P* - value**	≤0.0001	≤0.0001	0.003	0.5	0.6	0.002	0.07	0.06

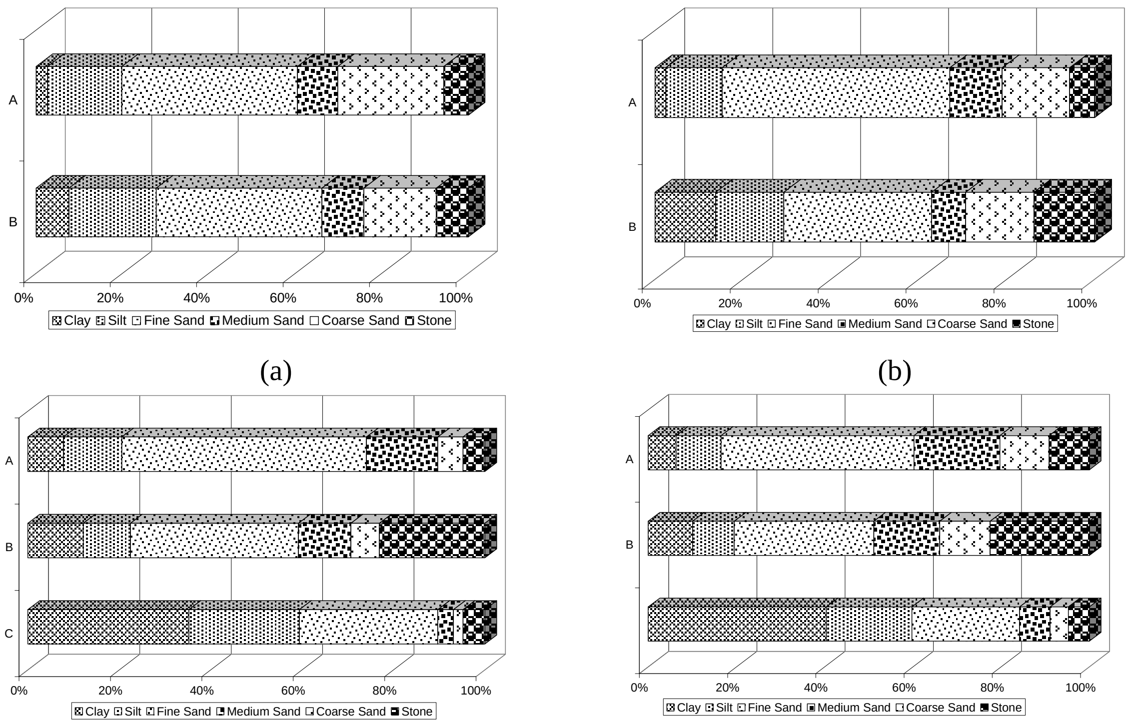
Table 4 Mean root distribution per 10 cm soil depth in soil profiles of selected commercial vineyards in Stellenbosch. (values in columns followed by same letters do not differ significantly).

The vineyards SwCS and SwSB were associated with a smaller total leaf area per shoot (Table 5), largely due to a smaller primary leaf area per shoot. The primary shoots were also significantly shorter at SwCS and SwSB (Table 5), despite having the same number of primary leaves, and thus nodes, as RuCS and RuSB. These differences were already noticeable by the phenological stage of berries pea-size (data not shown).



(a) (b) (c) (d)

Figure 1 Photos of representative soil profiles at (a) RuCS(1); (b) RuSB(1); (c) SwCS(2) and (d) SwSB(1).



(a) (b)

(c) (d)

Figure 2 Soil texture of representative soil profiles at (a) RuCS(1); (b) RuSB(1); (c) SwCS(2) and (d) SwSB(1).

Vineyard	Number of lateral leaves	Total lateral shoot length (mm)	Lateral leaf area (cm^2)	Number of primary leaves	Primary leaf area (cm^2)	Primary shoot length (cm)	Total leaf area (cm^2)
RuCS	34	87.3^{bc}	1266.2	16	1681.9^{a}	117.8^{a}	1866.9^{b}
RuSB	34	94.8^{c}	1330.1	16	1581.6^{a}	120.4^{a}	1596.1^{b}
SwCS	27	51.8^{a}	864.6	18	1305.3^{c}	94.0^{c}	1348.6^{a}
SwSB	33	65.0^{ab}	1013.4	15	1066.2^{b}	67.9^{b}	1344.5^{a}
***p*-value**	0.36	0.03	0.15	0.27	≤0.0001	≤0.0001	0.002

Table 5 Shoot length and leaf area per primary shoot for selected commercial vineyards in Stellenbosch (2005-2007). (Values in columns followed by same letters do not differ significantly at p<0.05).

Vineyard	Yield per meter cordon (kg.m^{-1})	Pruning mass per meter cordon (kg.m^{-1})	Yield: pruning mass	"Puissance"[1]
RuCS	1.4^{a}	0.77^{b}	2.2^{a}	1.0^{a}
RuSB	2.5^{c}	1.02^{c}	2.6^{ab}	1.2^{b}
SwCS	2.1^{b}	0.80^{b}	3.2^{b}	0.77^{c}
SwSB	2.8^{d}	0.51^{a}	6.7^{c}	0.82^{c}
***p*-value**	≤0.0001	≤0.0001	≤0.0001	≤0.0001

Table 6 Yield and pruning measurements for selected commercial vineyards in Stellenbosch (2005-2007). (Values in columns followed by same letters do not differ significantly at p<0.05).
1(Deloire et al. 2002)

The RuCS vineyard had a significantly lower yield and yield: pruning mass ratio that the SwCS, as did the RuSB compared to the SwSB (Table 6). The two Sw vineyards had significantly lower "puissance" or total estimated dry mater production than their counterparts at Ru (Table 6).

The lower total estimated dry matter production at the Sw vineyards could be related to increased water deficits across the season at these vineyards as compare to the Ru vineyards. The more negative means are predominantly due to more negative values at Sw before veraison (data not shown) but the increased accumulative water stress at the Sw vineyards over the season is shown by the lower dC_{13}/C_{12} values for these vineyards during 2007.

Vineyard	Mean pre-dawn LWP (-kPa)	d 13C/12C (‰)
RuCS	348 ^{a}	-26.89
RuSB	348 ^{a}	-28.00
SwCS	424 ^{b}	-23.80
SwSB	538 ^{c}	-24.64
***p*-value**	≤0.0001	

Table 7 Mean pre-dawn leaf water potential (2005-2007) and dC13/C12 (2007) for selected commercial vineyards in Stellenbosch (Values in columns followed by same letters do not differ significantly at p<0.05).

These increased water deficits at the Sw vineyards were also associated with higher juice pH values and K content in berry skins and lower malic acid content. It would appear, however, that the total berry anthocyanins were increased at SwCS compared to RuCS.

Vineyard	TSS (ºB)	pH	TTA ($g.L^{-1}$)	Tartaric acid ($g.L^{-1}$)	Malic acid ($g.L^{-1}$)	Total polyphenols ($AU.g^{-1}$)	Anthocyanins ($mg.g^{-1}$)	Kskins
RuCS	23.1^{b}	3.54 ^{b}	4.82 ^{a}	1.86	3.38 ^{a}	2.81	0.47 ^{a}	227.3 ^{a}
RuSB	19.8^{a}	3.21^{a}	8.56 ^{b}	3.30	7.78 ^{b}			312.9 ^{b}
SwCS	20.9^{a}	3.80 ^{c}	4.31 ^{a}	2.35	2.83 ^{a}	1.90	1.43 ^{b}	289.9 ^{ab}
SwSB	20.6^{a}	3.54 ^{b}	5.05 ^{a}	1.23	3.20 ^{a}			314.3 ^{b}
***p*-value**	0.02	≤0.0001	≤0.0001	0.26	0.002	0.07	0.0005	0.04

Table 8 Berry composition on last measurement date before harvest for selected commercial vineyards in Stellenbosch (2005-2007). (Values in columns followed by same letters do not differ significantly at p<0.05).

Sensorially, however, the SwCS wines were scored as having significantly lower colour, tannins and as being less full on mouthfeel than the RuCS wines. With respect to sensory characteristics of the Sauvignon blanc wines, they only differed significantly with respect to the green pepper aroma characteristic, with the Ru wine having a significantly higher score than the Sw wine.

Conclusions

For each cultivar, the two different terroirs result in significantly different response in terms of grapevine performance and wine style. This response was not always correctly predicted by the previous terroir study, although the yield:pruning mass ratio, the total estimated dry matter production (or "puissance"), the juice pH (for Cabernet Sauvignon) appeared to follow the correct patterns, even if the values were not true in all cases. As regards the sensory characteristics of the wines, it is difficult to compare the results as the aromas evaluated in this study are not identical to those described in the previous study but in general for the Sauvignon blanc, it would appear that the combine fresh vegetative characteristics (green pepper, grassy) would not differ and would be in the order fo the valued predicted, while the tropical fruit aromas (pineapple, guava) would be higher for SwSB, as predicted. For Cabernet Sauvignon, the berry aromas were higher for RuCS, opposite to what was predicted. The previous study showed a strong effect of climate and the results were based on 7-years of data. In this study only 2 to 3 years of data have been included.

The different environments presented in this paper induce different grapevine responses. It appears as if the different soil textural properties induce different degrees of plant water stress across the season and that this affected the leaf area, yield, berry composition and wine style. The contribution of climate cannot be ignored as these two sites would have resulted in very different mesoclimatic conditions. Inclusion of data from other sites and seasons are necessary to strengthen the results presented in this paper and to test the validity of the previous terroir studies in a more robust manner.

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