

Effects of Soil Parent Material and Climate on the Performance of *Vitis vinifera* L. cvs. Sauvignon blanc and Cabernet Sauvignon - Part II. Climate, Leaf Analysis, Juice Analysis and Wine Quality

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A five-year investigation (2004/05 to 2008/09) was carried out in two Sauvignon blanc and two Cabernet Sauvignon vineyards in the Helderberg area, Western Cape, South Africa. Soils, derived mainly from granite and shale, were identified in each vineyard. Climatic parameters were measured, while leaves and juice were analysed. Experimental wines were prepared and evaluated annually. The nutritional status of the leaf blades and petioles was not affected by soil parent materials in a consistent pattern. Juice N of grapevines on the shale-derived soil was usually higher than that of vines on the granite-derived soil. The effect of soil parent material on Sauvignon blanc wine style appeared to have been more distinct at the locality where wine quality was highest. At this locality, wine from the grapevines on shale-derived soil (higher water-holding capacity) was best in 2004/05 (dry season), while the reverse was true in the 2007/08 season (wet). The style and/or quality of Cabernet Sauvignon wines were affected to a greater extent by differences in soil parent materials, relative to Sauvignon blanc. Differences were especially noticeable during the cooler and wetter seasons. Better drainage in the case of the granite-derived soils, due to the higher coarse sand fraction, may have played a positive role during these seasons.

INTRODUCTION

Soil parent material is considered to have a potential-determining effect on wine character and quality (Wilson, 1998). These effects are not directly on wine quality, since it is mainly the physical properties of a soil that determine quality through the effects of variables such as drainage, soil temperature and water availability on vine growth patterns (Conradie *et al.*, 2002). According to research in Bordeaux (Seguin, 1983), classified vineyards owe their superiority to the ability of the soil to regulate the supply of water to the vines, rapidly draining excessive water but retaining sufficient water and releasing it at such a rate that, although the vines experience some stress towards ripening, this stress is not excessive. In the Coastal Region of South Africa, granite-derived soils were found to contain greater amounts of gravel and coarse sand, while shale-derived soils contained larger amounts of fine sand (Van Schoor, 2001; Conradie *et al.*, 2002; Shange & Conradie, 2012). Water-holding capacities generally tended to be highest in the shale-derived soils, while the effect of soil parent material on grapevine water constraints was fairly prominent in the

drier seasons (Shange & Conradie, 2012). Wine style and/or quality may well be affected by these differences between granite-derived and shale-derived soils. However, the impact of soil parent material on wine style and/or quality under similar climatic, topographic and vineyard management practices has not yet been evaluated scientifically.

For grapevines, luxury uptake of K may affect red wine quality negatively by increasing juice pH (Somers, 1975; Conradie, 1994; Kodur, 2011), and altering the acid balance of the juice and wine (Conradie & Saayman, 1989; Mpelasoka *et al.*, 2003). In a study on Sauvignon blanc in the Coastal Region of South Africa, soils originating from phyllitic shales contained the lowest K levels compared to those from granite (Conradie *et al.*, 2002). Wooldridge (1988) indicated that granite-derived soils are relatively rich in total K, but possess little capacity to prevent its release, potentially resulting in a luxurious short-term supply of plant-available K. Levels of water-soluble soil K were generally greater in granite-derived than in shale-derived soils (Shange & Conradie, 2012), suggesting that soil parent material may have an indirect effect on wine quality, through

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its relationship with K availability.

Root system development and efficiency could not be related directly to soil parent material and soil type (Shange & Conradie, 2012). However, in most cases root density tended to be higher in granite-derived soils, while cane mass and yield also tended to be higher for grapevines on granite-derived soils at some localities. The current research focuses on the effect of soil parent materials (granite and shale) on leaf and juice composition, as well as on wine style and/or quality, when climate, topography and vineyard management practices are similar.

MATERIALS AND METHODS

Experimental vineyards and layout

As previously described by Shange and Conradie (2012), the study was conducted over five seasons in four commercial vineyards (two x Sauvignon blanc and two x Cabernet Sauvignon) in the Helderberg Region, Western Cape, South Africa (Table 1). The Sauvignon blanc vineyards were designated as higher altitude (SH) and lower altitude (SL), and the Cabernet Sauvignon vineyards as were designated as CH and CL respectively. Locality CH was rain fed, whilst the others received supplementary drip irrigation (one or two irrigations per season). Within each vineyard, two soil parent materials were identified through identification of the underlying rock. The first parent material was granite of the Stellenbosch pluton, and the second was greywacke/phyllitic shale of the Namibian Malmesbury Group (Theron *et al.*, 1992). Experimental plots were selected on granite-derived and shale-derived soils. Aspects and gradients are shown in Table 1. Further details concerning the experiment layout and cultivation practices were described in Shange and Conradie (2012).

Climate

Automatic weather stations were erected at each locality, except at SL, which was situated close to CL (≈ 200 m). Data were collected and processed by the Agricultural Research Council's Institute of Soil, Water and Climate (ISCW). Weather parameters such as temperature, rainfall and hours of sunshine were recorded. Hourly average data were used to calculate daily maximum, minimum and mean temperatures, number of hours with temperatures above 30°C and below 12°C, and growing degree-days (Amerine & Winkler, 1944). Weather stations were only erected during the course of the first growing season (2004/05), resulting in climatic data being unavailable for the first part of this season. Due to incomplete records, reliable data were also lacking for the 2005/06 summer months. In order to compare climatic conditions between the different seasons, data from a nearby weather station operated by the ISCW at Alto farm were used (Table 2). This station is situated at an altitude of 251 m, at 34.0140°S; 18.8558°E, and therefore the location was comparable to that of the weather stations at the experimental sites (Table 1).

Leaf analysis

Approximately 30 leaves per plot were sampled directly opposite clusters during fruit set (four localities x two soil parent materials x five seasons). Leaves and petioles were separated immediately after sampling, oven dried, extracted with 1.0 M KCl and analysed for N, P, K, Ca, Mg and Na according to the standard methods of Campbell and Plank (1998) and Miller (1998) by an accredited commercial laboratory.

TABLE 1

Characteristics of four experimental vineyards planted to Sauvignon blanc and Cabernet Sauvignon in the Helderberg area, Western Cape, South Africa.

Locality*	Scion/Rootstock	Soil parent material	Coordinates	Altitude (m)	Aspect	Slope (%)
SH	Sauvignon blanc/ 110 Richter	Granite	34.0254°S, 18.8588°E	417	NE	1
		Shale	34.0258°S, 18.8584°E	411	SW	15
SL	Sauvignon blanc/ 99 Richter	Granite	34.0216°S, 18.8399°E	227	NE	9
		Shale	34.0220°S, 18.8417°E	230	NE	6
CL	Cabernet Sauvignon/ 110 Richter	Granite	34.0188°S, 18.8409°E	224	W/NW	1
		Shale	34.0193°S, 18.8435°E	238	W/NW	7
CH	Cabernet Sauvignon/ 110 Richter	Granite	34.0303°S, 18.8450°E	270	W/NW	8
		Shale	34.0302°S, 18.8443°E	280	W/NW	15

*Sauvignon blanc (SH and SL) and Cabernet Sauvignon (CH and CL) experimental vineyards in Helderberg (S = Sauvignon blanc, C = Cabernet Sauvignon, H = High altitude, L = Low altitude).

Juice analysis

The target sugar content value for harvesting was 22.5°B to 23.0°B for Sauvignon blanc and 23.0°B to 24°B for Cabernet Sauvignon. However, due to the occurrence of *Botrytis cinerea* during some seasons at SL, the grapes had to be harvested before this target value could be reached in order to obtain healthy grapes. During harvest, at least six randomly selected bunches were crushed in a hydraulic press to obtain juice at each plot (four localities x two soil parent materials x five seasons). This juice was analysed for total soluble solids (TSS) by using a temperature-compensated Abbé refractometer, pH (654 Metrohm pH meter) and total titratable acidity (TTA), where 50 mL juice was titrated with 0.333 M NaOH to pH 7.0 and expressed as g tartaric acid/L. The rest of the juice was sent to an accredited commercial laboratory for N, P, K, Ca, Mg and Na analyses, which were carried out according to standard methods.

Experimental wines

For both Sauvignon blanc and Cabernet Sauvignon, approximately 40 kg to 60 kg of grapes were harvested from each plot, after which experimental wines were prepared by the research winery at ARC Infruitec-Nietvoorbij. Wine was made as described by Conradie (2001) and Myburgh (2011) for Sauvignon blanc and Cabernet Sauvignon respectively. Two replicates were fermented separately for each plot. Wines were bottled approximately four months after fermentation and then stored at 14°C until evaluation, which was about two months later. The tasting panel was made up of at least 14 wine tasters trained in the evaluation of Sauvignon blanc and Cabernet Sauvignon wines. Tasting took place in individual booths under white light and the wines were served in a completely randomised sequence. A 10 cm unstructured line scale was used by the judges to score specific aromatic parameters, from undetectable/unacceptable = 0 to prominent/excellent = 10. This method is based on the standardised system of wine aroma terminology (Noble *et al.*, 1987), which uses the following descriptors: fresh vegetative (green pepper, cut green grass, eucalyptus and mint), cooked vegetative (green beans, asparagus, olive and artichoke), dried vegetative (hay/straw, tea and tobacco), tropical fruit (pineapple, melon, banana and guava), dried fruit (strawberry jam, raisin, prune and fig) and spicy (liquorice, aniseed, black pepper and clove) characteristics for the description of Sauvignon blanc. Berry aroma (blackberry, raspberry, strawberry and black currant), as well as astringency, was also evaluated for Cabernet Sauvignon. General aroma intensity, fullness and overall wine quality were included for both cultivars.

Statistical analysis

Analysis of variance, using the five seasons as replicates, was performed on leaf and juice data by means of the general linear model (GLM) procedure of SAS statistical software version 9.1 (SAS, 2000). The Shapiro-Wilk test was performed to test for normality (Shapiro & Wilk, 1965). The wine sensory attributes were subjected to a factorial analysis of variance and the repeated measurements over the five seasons were used as a subplot factor. Student's *t* least significant differences were calculated at the 5% and 10%

TABLE 2
Climatic data for five growing seasons obtained from Alto farm weather station, situated close to the experimental sites in the Helderberg area.

Season	Rainfall (mm)		Spring temperature (°C)			Summer temperature (°C)			Mean February temperature (°C)
	Annual	Spring (Sept-Nov)	Summer (Dec-Feb)		Spring (Sept-Nov)		Summer (Dec-Feb)		
			Max	Min	Max	Min	Max	Min	
2004/05	501	59	22.85	12.60	17.20	27.80	16.60	21.74	22.18
2005/06	670	111	22.28	12.10	16.70	28.20	16.10	21.32	21.98
2006/07	803	133	23.09	13.00	17.50	27.10	16.10	20.97	20.97
2007/08	1033	224	21.81	11.90	16.40	28.50	16.60	21.92	22.16
2008/09	857	293	20.97	11.30	15.60	28.40	16.60	21.84	23.20
Average (2004-2009)	773	164	22.20	12.20	16.70	28.00	16.40	21.56	22.10
Long-term average (13 years, 1998 to 2011)	747	176	22.12	12.20	16.60	28.20	16.40	21.52	22.31

probability levels to compare treatment means (Snedecor & Cochran, 1980).

RESULTS AND DISCUSSION

Climate

Average values for climatic parameters, over the five experimental seasons, were similar to the long-term average (LTA) calculated from 1998 to 2011, even though appreciable differences occurred between individual seasons (Table 2). The 2004/05 season was characterised by low rainfall, especially during spring (117 mm below average) and summer (55 mm below average). In this season, spring temperatures were marginally higher than the LTA, largely due to high temperatures during November (data not shown). Summer temperatures, as well as mean February temperatures, were close to normal (Table 2).

During the 2005/06 growing season, rainfall was fairly normal during the winter (503 mm) and summer, but spring was dry, with rainfall 65 mm below average. Temperatures were normal during spring and summer. For the 2006/07 season, annual rainfall was marginally higher than the LTA, spring was relatively dry (43 mm less than the LTA), while summer rainfall was approximately 20 mm higher than the LTA. Spring was relatively warm (mean temperature nearly 1°C above average), but summer temperatures (especially maximum temperatures) were lower than the LTA. During the 2007/08 season, total rainfall (1 033 mm) was the highest experienced during the experimental period. Apart from high rainfall during winter, spring (48 mm above average) and summer (47 mm above average) were also relatively wet. Temperatures were low in September, high in October and exceptionally low in November (data not shown). Summer temperatures were marginally higher than the LTA (Table 2). In the last growing season (2008/09), total rainfall (857 mm) was 110 mm higher than the LTA. The latter was primarily due to wet conditions during spring, when precipitation was 117 mm higher than the LTA. Furthermore, mean and maximum temperatures during spring were 1.01°C and 1.15°C lower than the LTAs respectively, resulting in the coolest spring recorded during the investigation period. The month of January (2009) was also relatively cool (data not shown). The mean February temperature (23.20°C) was the

highest recorded during the investigation period (Table 2). This resulted in the mean temperature for the whole summer being close to normal.

Taking all of the above into consideration, the first two growing seasons (2004/05 and 2005/06) could be classified as dry, the third (2006/07) as normal and the last two (2007/08 and 2008/09) as wet. According to the spring temperatures, the 2008/09 growing season was cool, while 2004/05 and 2006/07 were the warmest. Mean summer temperatures varied by less than 1°C between the warmest (2007/08) and the coolest (2006/07) seasons.

Summer temperatures at the experimental sites during the last three years of the investigation are shown in Table 3. In general, temperatures tended to be lower at SH (higher altitude) than at CL and CH. This could be ascribed to lower minimum temperatures (e.g. number of hours with temperature < 12°C) at SH. Average temperatures were similar for CL and CH (Table 3). All three locations fall in Region III of the Winkler classification (Winkler *et al.*, 1974), with indices ranging from 1 700 to 1 900 during the investigation period.

Leaf analysis

Sauvignon blanc

At the Sauvignon blanc localities, petiole N and K were not affected by soil parent material (Table 4). However, petiole P, Ca and Mg were affected by the different soil parent materials. Petiole P of the grapevines on shale-derived soils was higher than that of vines on granite-derived soils at SL (Table 4). This result was in spite of soil P being similar in the upper soil layers (0 to 300 mm) of the shale-derived and granite-derived soils, viz. 33 mg/kg and 37 mg/kg respectively. Petiole Ca and Mg of the grapevines on shale-derived soils were higher than that of vines on the granite-derived soils at both SH and SL (Table 4). In the case of SH, this corresponded to the exchangeable soil Ca and Mg levels, which were higher in the shale-derived (2.62 cmol_c/kg and 0.72 cmol_c/kg respectively) than in the granite-derived soil (0.52 cmol_c/kg and 0.27 cmol_c/kg respectively). However, no differences were observed regarding exchangeable soil Ca and Mg at SL.

TABLE 3

Temperature regimes during the summer months at the experimental localities underlain by different soil parent materials in the Helderberg area (means for three seasons, 2006/07 to 2008/09).

Month	Locality*	Temperature (°C)			Temperature > 30°C hours	Temperature < 12°C hours
		Maximum	Minimum	Mean		
December	SH	24.93	14.75	19.3	20	22
	CL	25.52	15.46	20.3	22	7
	CH	24.94	16.16	20.3	21	4
January	SH	27.36	15.92	21.0	47	3
	CL	27.65	16.48	21.7	47	2
	CH	26.87	17.37	21.7	45	0
February	SH	27.31	16.07	21.0	42	7
	CL	27.83	16.62	21.7	47	0
	CL	26.94	17.65	21.8	40	0

*Refer to Table 1 for a more detailed description.

Cabernet Sauvignon

As in the case of Sauvignon blanc, petiole N was not affected by the parent material, but values tended to be higher at CH than at CL (Table 4). Petiole P of grapevines on granite-derived soils was higher than that of vines on shale-derived soils at CL. A contrasting result was observed in the soil at CL, where the shale-derived soil (300 mm soil layer) contained more than double the amount of P (28 mg/kg) compared to the granite-derived soil (12 mg/kg). This pointed towards luxurious P uptake by grapevines on the granite-derived soil, even though the specific reason for this phenomenon was unclear. However, according to existing norms (Conradie, 1994), P was also adequately supplied to grapevines on the shale-derived soils. Petiole K was affected by soil parent material in both vineyards (CH and CL), but in a contrasting manner. Petiole K of grapevines on the granite-derived soils was higher than that of vines on the shale-derived soils at CH, while the opposite was true at CL (Table 4). This was in accordance with exchangeable soil K levels being higher in granite-derived (101 mg/kg) than in shale-derived soil (78 mg/kg) at CH, but lower in granite-derived (87 mg/kg) than in shale-derived soil (108 mg/kg) at CL. As mentioned in a previous article (Shange & Conradie, 2012), an application of 30 kg K/ha/yr is generally recommended for vineyards in this area, but larger amounts may have been applied at some of the localities. Petiole Ca of the grapevines on the shale-derived soils was higher than that of vines on the granite-derived soils at CH (Table 4), thus being in agreement with the values for soluble soil Ca (5.75 mg/kg vs. 10.9 mg/kg). Petiole Mg of grapevines on the shale-derived soil was higher than that of vines on the granite-derived soils at CH, while the opposite was true at CL (Table 4). Exchangeable soil Mg exhibited comparable trends at both sites (data not shown).

For both Sauvignon blanc and Cabernet Sauvignon grapevines, the distribution pattern of nutrients in the leaf blades (data not shown) was largely similar to that in the petioles. However, for both leaf petioles and blades, the nutritional status was not affected by soil parent material in a similar manner at the different localities, i.e. an element would be affected in a specific way at a certain locality, but not follow the same trend at another locality. This inconsistency, ascribed partly to the application of fertilisers, made it difficult to properly define the role of soil parent

materials on the nutrient status of leaf blades and petioles.

Juice analysis

Sauvignon blanc

For the Sauvignon blanc vineyards, sugar contents were higher at SH than at SL (Table 5). This was largely due to the occurrence of *Botrytis cinerea* during some seasons. Juice pH (average for the two localities) was marginally higher for the Sauvignon blanc grapevines on granite-derived soil than those on shale-derived soils (3.30 vs. 3.23), thus being in agreement with the findings of Shange (2009). Juice N was significantly higher for grapevines on shale-derived soil than on granite-derived soil at SL (Table 5). A similar trend (343 mg/L vs. 295 mg/L) could be discerned at SH. According to Gockowiak and Henschke (1992), the effect of N fertilisation on nitrogenous compounds in juice may be affected to a great extent by soil water status, suggesting that N uptake may have been enhanced by the higher water-holding capacity of the shale-derived soil, as shown by Shange and Conradie (2012).

Cabernet Sauvignon

In the case of Cabernet Sauvignon, sugar content was higher at the rain-fed locality, CH, than at CL, resulting in pH values being lower at CL (Table 5). Juice N was not significantly affected by soil parent material at both Cabernet Sauvignon localities; however, similarly to Sauvignon blanc, juice N values tended to be higher for grapevines on the shale-derived than those on the granite-derived soils at both CL and CH. In comparison to previously reported juice P values (Conradie & Saayman, 1989; Conradie, 2001), those for Cabernet Sauvignon vines on the shale-derived soil at CL appeared to be lower. However, juice P values appeared to be "acceptable" for Cabernet Sauvignon grapevines at CH and for those on the granite-derived soil at CL. In accordance with petiole P, juice P was affected by soil parent material at CL, viz. higher for juice on granite-derived soils than on shale-derived soils (Table 5). Soil parent material did not affect juice K significantly at any of the localities, in spite of petiole K having been higher for the shale-derived soil at CL and for the granite-derived soil at CH. However, at the rain-fed locality (CH), juice K tended to be higher for grapevines on the granite-derived soil (1 411 mg/L vs. 1 298 mg/L).

As in the case of petioles and leaf blades, parent material

TABLE 4

Petiole nutrient levels of Sauvignon blanc and Cabernet Sauvignon grapevines on granite-derived and shale-derived soils at four localities in the Helderberg area (means for five seasons, 2004/05 to 2008/09).

Element (%)	Sauvignon blanc				Cabernet Sauvignon			
	SH ⁽¹⁾		SL ⁽¹⁾		CL ⁽¹⁾		CH ⁽¹⁾	
	Granite	Shale	Granite	Shale	Granite	Shale	Granite	Shale
N	0.68 a ⁽²⁾	0.74 a	0.72 a	0.67 a	0.54 b	0.55 b	0.58 ab	0.61 a
P	0.47 b	0.49 ab	0.47 b	0.58 a	0.57 b	0.35 c	0.93 a	0.82 a
K	1.77 b	1.47 b	2.45 a	2.80 a	1.71 c	2.55 b	3.56 a	2.04 c
Ca	1.67 c	1.87 ab	1.73 bc	1.98 a	1.97 b	1.85 b	1.82 b	2.21 a
Mg	0.80 b	0.95 a	0.64 c	0.82 b	1.02 b	0.81 c	1.10 b	1.20 a

⁽¹⁾Refer to Table 1 for a more detailed description.

⁽²⁾Different letters within the same row for each cultivar denote significant differences ($p \leq 0.1$).

did not affect juice composition in a consistent way at both the Sauvignon blanc and Cabernet Sauvignon localities, apart from juice N generally tending to be higher for grapevines on shale-derived soils. This suggests that soil parent material may have an effect on wine quality through its effect on fermentation rate. Levels of juice K were hardly affected by parent material, suggesting that it is unlikely that wine quality would have been affected on account of different K levels.

Experimental wines

Sauvignon blanc

The style and quality of Sauvignon blanc wine differed seasonally, probably on account of variations in climatic conditions (Table 2). Wine quality for the five seasons was rated from “best” to “average” and “below average”, depending on the scores allocated for aroma intensity, overall quality and fullness. On the basis of the seasonal averages (Table 6), the 2004/05 vintage could be classified as “best”, 2005/06, 2006/07 and 2007/08 as “average”, while 2008/09 was “below average”.

High values for aroma intensity, overall wine quality, fullness, fresh and cooked vegetative characteristics, as well as tropical fruit (Table 6), reflected the reason for the 2005 vintage being classified as best. Wine from the shale-derived soils received a higher score for fresh vegetative character at SH and for dried vegetative character at SL. This suggests that the wines from the shale-derived soils may have been marginally better, while climate-soil interactions may have been optimal during this warm and dry season. For the 2005/06 and 2006/07 seasons, when climatic conditions were classified as “dry” and “normal” respectively, wine quality was classified as average. Wine quality differed only marginally between the granite-derived and shale-derived soils in both seasons. During the 2007/08 season, when rainfall was exceptionally high (Table 2), wine quality was again classified as being of average standard. Wine from the granite-derived soil at SH scored higher for cooked vegetative character, while wine from the shale-derived soil at SL scored higher for fresh vegetative, cooked vegetative and tropical fruit characteristics. This suggests that wine

from the granite-derived soil at SH was of superior quality in comparison to its shale-derived soil counterpart, while the reverse was true at SL. During this wet season, better drainage in the granite-derived soil may have been a positive factor at SH. The reason for a different pattern at SL was unclear, but higher acidity may have been a negative factor for wine from the granite-derived soil (Table 6). As reported previously (Shange & Conradie, 2012), botrytis infections may also have been more severe for grapevines on the granite-derived soil, where the number of leaf layers tended to be highest.

The quality of the 2009 vintage was classified as below average, but wines from SH were still of better quality than those from SL, as evidenced by higher scores for overall quality and fullness (Table 6). Cooked and dry vegetative characteristics were higher for the shale-derived than for the granite-derived soils at SH, thus being in contrast with the results from the previous season. The trend for cooked vegetative characteristics was also reversed, with wine from the granite-derived soil at SL receiving a higher score (Table 6).

The fact that the grapevines responded differently in 2007/08 and 2008/09 may have been on account of rainfall not having been quite as high in 2008/09 as in 2007/08, and/or cool conditions during the spring of 2008/09 (Table 2). In view of the different responses during the different seasons, the average values for the five seasons were reasonably similar for the individual sites (Table 6). Aroma intensity was higher for the granite-derived than the shale-derived soils at SH, probably on account of the trends observed during the 2004/05 and 2007/08 seasons. No other differences could be detected within the individual localities, but fairly large differences occurred between the two localities, with fullness and overall quality higher at SH than at SL (Table 6). This may have been due partly to SH being marginally cooler than SL. Furthermore, vineyard management was also observed visually to have been better at SH than at SL.

Cabernet Sauvignon

In comparison with Sauvignon blanc, the quality of Cabernet Sauvignon varied to a lesser extent from season to season.

TABLE 5

Juice parameters and nutrient levels of grapevines on granite-derived and shale-derived soils at Sauvignon blanc (SH, SL) and Cabernet Sauvignon (CL, CH) localities in the Helderberg area (means for five seasons, 2004/05 to 2008/09).

Analyses	SH ⁽¹⁾		SL ⁽¹⁾		CL ⁽¹⁾		CH ⁽¹⁾	
	Granite	Shale	Granite	Shale	Granite	Shale	Granite	Shale
Sugar (⁰ B)	23.7 a ⁽²⁾	23.0 a	21.7 b	21.7 b	22.9 b	23.2 b	24.1 a	23.9 a
TTA (g/L)	7.92 b	8.66 a	8.48 a	8.18 ab	7.46 a	7.12 a	7.60 a	7.56 a
pH	3.23 bc	3.15 c	3.37 a	3.31 ab	3.22 c	3.31 bc	3.59 a	3.51 ab
N (mg/L)	295 a	343 a	184 b	281 a	258 b	289 ab	301 ab	342 a
P (mg/L)	51.31 a	53.01 a	59.33 a	61.38 a	133 a	78.50 b	132 a	124 a
K (mg/L)	1031 a	1054 a	1235 a	1218 a	1201 a	1185 a	1411 a	1298 a
Ca (mg/L)	37.0 a	39.5 a	39.3 a	31.3 a	36.2 a	44.5 a	36.9 a	59.3 a
Mg (mg/L)	86.9 a	84.0 a	77.5 ab	66.1 b	94.1 a	95.2 a	101.0 a	89.5 a

⁽¹⁾Refer to Table 1 for a more detailed description.

⁽²⁾Different letters within the same row for each cultivar denote significant differences ($p \leq 0.1$).

TABLE 6
Wine sensory parameters⁽¹⁾ for Sauvignon blanc grapevines on granite-derived and shale-derived soils at two localities in the Helderberg area.

Season	Locality ⁽²⁾	Soil parent material	Aroma intensity	Overall quality	Fullness	Fresh vegetative ⁽³⁾	Cooked vegetative ⁽⁴⁾	Dried vegetative ⁽⁵⁾	Tropical fruit ⁽⁶⁾	Spicy ⁽⁷⁾	Acidity
2004/05	SH	Granite	6.72 a ⁽⁸⁾	5.64 a	5.31 ab	4.12 b	3.45 a	1.82 ab	4.90 a	1.79 a	5.76 a
		Shale	6.14 a	5.78 a	5.41 a	4.90 a	3.50 a	1.94 ab	4.15 a	1.33 a	5.41 a
	SL	Granite	6.07 a	5.68 a	5.14 ab	4.44 ab	2.82 a	1.59 b	4.17 a	2.00 a	6.01 a
		Shale	6.36 a	5.71 a	4.76 b	4.30 ab	2.76 a	1.96 a	4.89 a	1.63 a	5.87 a
2005/06	SH	Granite	5.60 a	5.07 ab	4.84 a	3.56 a	2.17 a	1.30 a	4.00 a	0.83 a	4.84 a
		Shale	5.74 a	5.41 b	5.12 a	3.98 a	1.71 a	1.32 a	4.54 a	0.60 a	5.02 a
	SL	Granite	5.63 a	4.68 a	4.87 a	3.74 a	1.62 a	1.22 a	4.12 a	0.77 a	5.20 a
		Shale	5.48 a	5.05 ab	4.89 a	3.78 a	1.61 a	0.97 a	3.76 a	0.62 a	5.46 a
2006/07	SH	Granite	5.84 a	5.25 a	4.84 a	4.35 a	2.70 a	2.95 a	4.28 a	2.23 a	4.88 b
		Shale	5.57 ba	5.21 a	5.12 a	4.21 a	2.17 b	2.85 a	4.69 a	2.22 a	4.98 ba
	SL	Granite	5.07 b	4.81 a	4.87 a	3.85 a	3.24 a	2.44 a	4.22 a	2.30 a	5.38 a
		Shale	5.60 ba	5.04 a	4.89 a	4.71 a	3.36 a	2.42 a	4.22 a	2.62 a	4.93 ba
2007/08	SH	Granite	5.60 a	5.13 a	4.78 a	3.83 ab	3.02 ab	1.59 b	3.36 ab	1.54 a	5.32 b
		Shale	4.76 ab	5.35 a	4.70 a	3.07 ab	2.26 c	1.58 b	3.47 ab	1.52 a	5.59 ab
	SL	Granite	4.38 b	4.58 a	4.55 a	2.81 b	2.85 bc	2.07 ab	2.49 b	1.46 a	6.07 a
		Shale	5.24 ab	4.93 a	4.35 a	4.09 a	3.71 a	2.54 a	3.95 a	1.54 a	5.24 b
2008/09	SH	Granite	4.78 a	5.02 a	4.93 a	3.92 a	2.55 bc	2.78 b	3.53 a	2.28 a	5.53 a
		Shale	4.74 a	4.62 ab	4.71 ab	3.65 ab	3.67 a	3.46 a	2.98 a	1.95 a	5.35 ab
	SL	Granite	4.73 a	4.20 bc	4.27 b	3.35 bc	2.91 b	2.25 b	3.08 a	1.83 ab	5.24 b
		Shale	4.37 a	3.81 c	4.15 b	2.97 c	2.22 c	2.63 b	3.25 a	1.42 b	4.91 a
Average	SH	Granite	5.71 a	5.11 ab	5.02 a	3.91 a	2.73 a	2.05 a	3.90 a	1.73 a	5.23 a
		Shale	5.38 b	5.24 a	5.01 a	3.95 a	2.64 a	2.25 a	3.98 a	1.51 a	5.21 a
	SL	Granite	5.16 b	4.74 c	4.77 b	3.58 a	2.65 a	1.97 a	3.57 a	1.65 a	5.49 a
		Shale	5.41 ab	4.91 bc	4.70 b	3.97 a	2.74 a	2.11 a	3.99 a	1.57 a	5.28 a

⁽¹⁾As evaluated by an experienced panel on a 10 cm unstructured line scale (undetectable/unacceptable = 0, prominent/excellent = 10), ⁽²⁾Refer to Table 1 for a more detailed description, ⁽³⁾Green pepper, cut green grass, eucalyptus and mint, ⁽⁴⁾Green beans, asparagus, olive and artichoke, ⁽⁵⁾Hay/straw, tea and tobacco, ⁽⁶⁾Pineapple, melon, banana and guava, ⁽⁷⁾Liquorice, aniseed, black pepper and clove, ⁽⁸⁾Different letters within the same column denote significant differences during specific seasons ($p \leq 0.05$).

Scores for overall quality, aroma intensity and fullness pointed towards “average” quality during the three “dry” seasons (2004/05, 2005/06 and 2006/07), as well as during one of the “wet” seasons (2008/2009). However, wine quality was “below average” during the other “wet” season (2007/08). Results as obtained at the different experimental localities over the five-year period are shown in Table 7.

In contrast to Sauvignon blanc, the 2005 vintage for Cabernet Sauvignon was not designated as the best. No major effects of soil parent material could be identified. However, vegetative and berry characteristics tended to be highest for wine from the shale-derived soil at CL. Aroma intensity, overall quality and fullness were highest for the 2006 vintage wine from the shale-derived soil at CL, suggesting that the “best” wine (most typical of Cabernet Sauvignon) was produced from the shale-derived soil at this site. This implied that the higher water-holding capacity of the shale-derived soil may have been beneficial for wine quality during this dry season. Differences were less pronounced at CH, with vegetative character higher for wine from the granite-derived soil (Table 7). Berry character for wines from the granite-derived soil was highest during the 2006/07 season (“normal” climatic conditions) at CL, suggesting that wine style may have been more typical of Cabernet Sauvignon in comparison to wine from the shale-derived soil.

In the 2007/08 season, with quality being “below average”, the effects of soil parent material were fairly prominent at both sites. Wine from the granite-derived soil at CL received higher scores for aroma intensity, overall quality, fullness and berry characteristics, with wine from this soil also scoring the highest for overall quality and fullness at CH (Table 7). During this particularly wet season, wine quality for grapevines on granite-derived soils appeared to have been enhanced. Soil parent material effects were again fairly prominent for the 2009 vintage, with wines being of acceptable quality (Table 7). Aroma intensity, overall quality, fullness, and berry and spicy characteristics for wines from the granite-derived soils were highest at CL, thus being in agreement with the results obtained during the previous season. Soil parent material effects were less prominent at CH than during the previous season, possibly on account of a “levelling” effect of low spring temperatures (Table 2). However, wine from the granite-derived soil was still “best” in terms of higher scores for vegetative and spicy characteristics. Wine quality and/or style were not affected by soil parent material when averages for the five seasons were compared for individual sites (Table 7), possibly due to seasonal variations. However, the vegetative character tended to be higher and berry characteristics lower for wine from the granite-derived soils at the rain-fed site (CH).

The above-mentioned results suggest that the style and/or quality of Sauvignon blanc and Cabernet Sauvignon wines were affected to some extent by differences in soil parent material. Responses obtained during the different seasons, may be summarised as follows:

2004/05: Wine style and/or quality tended to be best for shale-derived soils at three of the sites (SH, SL and CL), while no differences could be detected at CH. The higher water-holding capacities of the shale-derived soils may have been a positive factor during this dry season.

TABLE 7
Wine sensory parameters⁽¹⁾ for Cabernet Sauvignon grapevines on granite-derived and shale-derived soils at two localities in the Helderberg area.

Season	Locality ⁽²⁾	Soil parent material	Aroma intensity	Overall quality	Fullness	Vegetative ⁽³⁾	Berry ⁽⁴⁾	Spicy ⁽⁵⁾	Colour	Astringency	Acidity
2004/05	CL	Granite	6.27 b ⁽⁶⁾	5.50 a	5.50 a	4.28 a	4.26 b	2.40 a	7.68 b	5.09 a	5.92 a
		Shale	6.83 ab	6.02 a	6.02 a	4.73 a	5.05 ab	2.74 a	7.55 b	4.53 b	5.30 b
2005/06	CH	Granite	7.01 a	5.98 a	5.98 a	5.05 a	5.29 a	3.12 a	7.63 b	4.58 b	4.68 c
		Shale	6.53 ab	6.09 a	6.09 a	4.43 a	5.82 a	3.00 a	7.47 a	4.53 b	5.10 b
2005/06	CL	Granite	5.45 c	4.68 b	4.70 b	3.85 b	4.79 b	2.13 b	7.18 b	4.35 b	5.13 a
		Shale	6.11 b	5.54 a	5.25 a	4.55 b	5.38 ab	2.51 ab	7.81 a	4.73 b	5.00 a
2006/07	CH	Granite	6.79 a	5.89 a	5.61 a	5.44 a	5.03 ab	2.98 a	7.82 a	4.80 a	5.14 a
		Shale	6.49 ab	5.74 a	5.49 a	4.53 b	5.73 a	2.39 ab	7.74 a	4.94 a	5.48 a
2006/07	CL	Granite	5.82 b	5.08 bc	4.31 bc	4.78 bc	4.62 a	2.48 b	6.99 ab	4.60 a	4.59 b
		Shale	5.72 b	4.92 c	4.19 c	4.87 bc	3.83 b	2.39 b	6.45 b	3.88 b	5.34 a
2006/07	CH	Granite	6.74 a	5.93 a	5.48 a	5.82 a	4.56 ba	3.43 a	6.78 b	4.54 a	5.04 ba
		Shale	6.49 b	5.57 ab	4.91 ba	5.59 ba	4.85 a	3.05 ba	7.49 a	4.91 a	5.38 a

TABLE 7 (CONTINUED)

Season	Locality ⁽²⁾	Soil parent material	Aroma intensity	Overall quality	Fullness	Vegetative ⁽³⁾	Berry ⁽⁴⁾	Spicy ⁽⁵⁾	Colour	Astringency	Acidity
2007/08	CL	Granite	5.99 a	5.40 a	4.88 a	4.51 a	5.28 a	2.83 a	6.83 a	2.90 a	4.88 a
		Shale	4.58 b	3.99 b	3.40 a	4.09 a	3.50 b	2.80 a	5.23 b	2.03 b	3.40 b
2008/09	CH	Granite	4.95 b	5.40 a	5.23 a	3.97 a	4.16 ab	2.59 a	6.55 a	2.76 ab	5.23 a
		Shale	5.22 ab	4.32 b	3.85 b	3.87 a	3.90 b	2.35 a	5.55 b	2.07 b	3.85 b
Averages	CL	Granite	6.56 a	5.94 a	6.20 a	4.35 bc	5.68 a	2.72 b	6.99 a	4.28 ab	5.25 a
		Shale	5.83 b	4.70 b	4.97 c	4.18 c	4.47 c	1.73 c	6.28 b	4.45 a	4.87 a
Averages	CH	Granite	6.79 a	5.63 a	5.50 b	5.88 a	5.03 b	4.54 a	6.68 a	3.98 b	5.15 a
		Shale	6.43 a	5.67 a	5.45 b	4.96 b	5.29 ab	3.21 b	6.83 a	4.02 b	5.08 a
Averages	CL	Granite	5.98 a	5.13 a	4.97 ab	4.62 b	4.81 a	2.49 b	7.10 a	4.35 a	5.40 a
		Shale	6.01 a	5.05 a	4.75 b	4.78 ab	4.51 a	2.61 b	6.78 a	4.18 a	5.11 ab
Averages	CH	Granite	6.43 a	5.55 a	5.41 a	5.11 a	4.67 a	3.18 a	7.20 a	4.21 a	4.86 b
		Shale	6.31 a	5.45 a	5.22 ab	4.66 ab	5.06 a	2.87 ab	6.99 a	4.22 a	5.21 ab

⁽¹⁾As evaluated by an experienced panel on a 10 cm unstructured line scale (undetectable/unacceptable = 0, prominent/excellent = 10), ⁽²⁾Refer to Table 1 for a more detailed description, ⁽³⁾Green pepper, green grass, eucalyptus, mint, green beans, asparagus, olive, artichoke, hay/ straw, tea and tobacco, ⁽⁴⁾Blackberry, raspberry, strawberry, black currant, ⁽⁵⁾Liquorice, aniseed, black pepper and clove, ⁽⁶⁾Different letters within the same column denote significant differences during specific seasons ($p \leq 0.05$).

2005/06: Rainfall was below average, but not as dry as in 2004/05. Wine style and/or quality were best for the shale-derived soil at CL, but no effect of soil parent material could be detected at the other sites.

2006/07: Rainfall was normal, but spring temperatures were high. Wine style and/or quality were best for the granite-derived soil at CL, with no differences at the other sites.

2007/08: Wine style and/or quality were best for the granite-derived soils at SH, CH and CL, while wine from the shale-derived soil was best at SL. As already mentioned, better drainage of the granite-derived soil may have been a positive factor during this very wet season. The reason for the different pattern at SL is unclear, but at this locality botrytis infection may have been more severe for grapevines on the granite-derived soil.

2008/09: Rainfall was again high, wine style and/or quality were highest for the granite-derived soils at SL, CH and CL, while quality was highest for the shale-derived soil at SH. The fact that the grapevines at SH responded differently in 2007/08 and 2008/09 may have been on account of rainfall not having been quite as high in 2008/09 as in 2007/08, and/or cool conditions during the spring of 2008/09 (Table 2).

CONCLUSIONS

Juice N of the grapevines on the shale-derived soils tended to be higher than that of vines on the granite-derived soils. Soil parent material may therefore have an effect on wine quality, through its effect on fermentation rate. This warrants further investigation. In this study, juice K was hardly affected by soil parent material. However, soil preparation before planting, as well as K fertilisation, may have negated the effect of parent material to some extent. Wine style and/or quality of Sauvignon blanc seems to be affected by soil parent material differences to a lesser extent than that of Cabernet Sauvignon. However, wine style and/or quality of Cabernet Sauvignon was not affected by soil parent material in a consistent manner. During dry seasons the higher water-holding capacity of the shale-derived soils may affect wine quality positively. In contrast, better wine seems to be obtained from granite-derived soil during cooler and wetter seasons. This suggests that the extent of the effect of the soil parent material on wine style and/or quality turns out to be determined by seasonal weather conditions.

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