EFFECTS OF SOIL AND CLIMATE ON WINE STYLE IN THE BREEDE RIVER VALLEY OF SOUTH AFRICA: SAUVIGNON BLANC AND CABERNET SAUVIGNON

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Abstract

The effects of soil and climate on wine style were evaluated for irrigated vineyards at two different localities in the Breede River Valley of South Africa. One locality was cooler than the other, largely on account of lower night temperatures. Measurements were done for Sauvignon blanc and Cabernet Sauvignon, at both localities. Two contrasting soil forms were identified within both Sauvignon blanc vineyards. At the cooler locality the first soil was sandy (4% clay), while the second was more clayey (21% clay). This resulted in a water holding capacity of 62 mm/m for the first, in comparison to 157 mm/m for the second. A comparable situation existed within the Sauvignon blanc vineyard at the warmer locality, with water holding capacity ranging from 66 mm/m to 112 mm/m for the two soils. Only one soil form (sandy loam, containing 18% clay) was identified for Cabernet Sauvignon at the cooler locality. At the warmer locality, however, two divergent soil forms occurred within the Cabernet Sauvignon vineyard. The first contained only 2% clay, in comparison to 37% for the second, resulting in widely divergent soil structures.

For Sauvignon blanc, aroma intensity was higher in wines from the cooler locality than in those from from the warmer locality, irrespective of soil form. At the cooler locality different soil forms also induced divergent styles. In general, wine from the sandy soil was regarded as more "typical", in comparison to the one from the more clayey soil. At the warmer locality the style of Sauvignon blanc was not affected by soil form. In the case of Cabernet Sauvignon, aroma intensity was comparable for the wine from the cooler locality and the one from the clayey soil at the warmer locality. However, styles were widely divergent, with wine from the cooler locality exhibiting a pronounced grass character, in comparison to a berry character for the one from the warmer locality. At the warmer locality the style of Cabernet Sauvignon was also affected by soil form, with berry character and aroma intensity being lower in wine from the sandy soil.

Results indicated that the style of wines from Breede River Valley is not only affected by climate, but also by soil form. The effect of soil form can be diminished where irrigation is scientifically scheduled, but not entirely eliminated.

Resumé

Les effets du sol et du climat sur le style de vin ont été évalués pour des vignes irriguées à deux endroits différents de la vallée de la Breede, en Afrique du Sud. L'un des 2 endroits est cependant plus froid que l'autre, principalement en raison de températures nocturnes plus basses. Des mesures ont été faites pour le Sauvignon blanc et le Cabernet Sauvignon, aux deux localités. Deux formations pédologiques ont été identifiées au sein des deux vignobles de Sauvignon Blanc. A l'endroit le plus frais, le premier sol est sableux (4% d'argile), tandis que le second est plus argileux (21% argile). Par conséquent, la capacité de rétention d'eau (sur la profondeur racinaire) est de 62 mm/m pour le premier et de 157 mm/m pour le second. Une situation comparable existe au sein du vignoble de

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Sauvignon blanc à l’endroit plus chaud, avec une capacité de rétention d’eau allant de 60 mm/m pour le premier sol à 112 mm/m pour le deuxiéme. Une seule formation pédologique (terreau sableux contenant 18% d’argile) a été identifiée pour le Cabernet Sauvignon à l’endroit le plus frais. Par contre, à l’endroit le plus chaud, on trouve deux sols divergeants. Le premier contient seulement 2% d’argile, alors que le second en contient 37%, aboutissant à des structures de sol largement divergeantes.

Pour le Sauvignon blanc, l’intensité des arômes était plus élevée dans les vins de la localité la plus fraîche que celle dans les vins de la localité de la plus chaude, et ceci indépendemment du sol. A l’endroit le plus frais, les différents sols ont aussi produit des styles differents. En général, les vins issus du sol sableux sont dits “typiques” par comparaison à ceux issus du sol plus argileux. A l’endroit plus chaud, le style du Sauvignon blanc n’a pas été affecté par le sol. Dans le cas du Cabernet Sauvignon, l’intensité arômatique était comparable entre les vins issus de l’endroit plus frais et les vins issus du sol argileux de l’endroit le plus chaud. Cependant, les styles de vins étaient largement divergents, ainsi les vins de l’endroit le plus frais révélaient un caractère herbacé prononcé, alors que les baies dominaient pour le vin de la localité la plus chaude. A l’endroit le plus chaud, le style du Cabernet Sauvignon était aussi affecté par le sol, avec des notes de baies et une intensité arômatique plus faible pour les vins issus du sol sableux.

Les résultats indiquent que le style de vin de la vallée de la Breede n’est pas seulement affecté par le climat, mais aussi par la formation pédologique. L’effet du sol peut-être dimimuée où l’irrigation est scientifiquement programmée, mais pas entièrement éliminée.

INTRODUCTION

The wine producing regions of South Africa are characterised by many diverse climates, ranging from Mediterranean to semi-arid (Carey *et al.*, 2004). Until recently, most studies, aimed at quantifying the effect of soil and climate on wine style, have been done in the Coastal Region, largely comprising the districts of Stellenbosch, Paarl, and Malmesbury. This Region has a Mediterranean climate, with mean annual rainfall around 690 mm (Conradie 2001). However, dry conditions, with total rainfall of only 121 mm, are experienced from November to March. Even though irrigation is increasingly being practised during the pre-harvest period, rain-fed vineyards are still commonly encountered in areas where irrigation water is not available. Within this Region, the style of Sauvignon blanc wines from different localities in Stellenbosch/Klein Drakenstein was largely affected by seasonal variations in temperature and rainfall (Bonnardot *et al.*, 2000). Different wine styles could also be identified for rain-fed Sauvignon blanc vineyards from different terrains, each with an unique topo-climate, in Stellenbosch/Durbanville (Conradie, 1998). The foregoing appears to be in agreement with the suggestion that climate will usually have a dominant effect on wine character, in warmer wine producing countries (Rankine *et al.*, 1971; Winkler *et al.*, 1974). However, the different regions in South Africa are also characterised by many diverse soil forms, within each climate-type. Studies performed in the 1970’s (Saayman, 1977), suggested that soil type can also have a marked effect on wine quality under rain-fed conditions, due to the hydromorphic properties of the soil, in relation to the prevailing and seasonal climate. In a study with Cabernet Sauvignon in Stellenbosch and it’s surrounds, the acidity of the sub-soil appeared to be a dominant site-related factor, affecting the grapevine and wine characteristics (Carey, 2002). This was ascribed to the negative effect of sub-soil acidity on root growth, thereby also affecting the water status of the grapevine. In the Coastal Region, wine style is therefore also related to soil type, especially to the water-holding capacity of a specific soil.

In contrast to the Coastal Region, the Breede River Valley which largely comprises the districts of Worcester and Robertson, experiences a semi-arid climate, with annual rainfall, mainly in winter, of less than 300 mm. All grapevines in this Region are irrigated on a regular basis. Under these conditions, it may be argued that wine style will be dominantly affected by climate, on account of the effect of soil form being eliminated by means of scientifically scheduled irrigation. The main aim of this investigation was to quantify the effect of soil form on wine style, for intensively irrigated vineyards from this Region. In view of the study being conducted in commercial vineyards, with the prerequisite being different meso-climates/soil types at different localities, availability of sites was limited, particularly since growers will often use different rootstocks on different soil types. The investigation must therefore be regarded as a preliminary "case study", carried out under conditions that will normally apply in the Region.

MATERIALS AND METHODS

The investigation was conducted over three seasons (2000/2001 to 2002/2003) at two localities within the district of Robertson. The localities (A and B) were approximately 15 km apart. Two commercial vineyards (1x Sauvignon blanc and 1x Cabernet Sauvignon) were identified for experimental purposes, at each locality. Grapevines were approximately 15 years old at the start of the investigation and trained onto vertical trellis systems (one wire for the cordon arms and two to four wires for the foliage). The Sauvignon blanc vineyards and the Cabernet Sauvignon at A, were drip irrigated, while the Cabernet Sauvignon at B was irrigated with micro-sprinklers. Changes in soil water content were measured weekly by means neutron probes at 300 mm depth intervals, down to a depth of 1200 mm. Irrigation scheduling was based on these measurements. Between budbreak and harvest, vineyards were generally irrigated once per week, while irrigation was applied at longer intervals during the rest of the season. Soil water content was replenished up to field capacity, following each irrigation. Except for the Cabernet Sauvignon at locality B, two contrasting soil forms (not more than 100 m apart) were identified within each vineyard (Table 1), using the South African Soil Classification System (Soil Classification Working Group, 1991). According to this system, soils are classified into soil forms on the basis of the presence and properties of master horizons. Further classification, into families, is based on A, B, and E horizon properties, degree of leaching, clay movement and wetness. Fairly large differences may therefore occur within a soil form. The water-holding capacities of the vineyard soils (2.5 kPa to 100 kPa) were measured, employing standard pressure-plate equipment.
The Sauvignon blanc at A was grafted onto 110 Richter, while those at B were grafted onto 99 Richter for the Fernwood soil form (loamy sand), and onto Ramsey for the Valsrivier (sand clay loam). The Cabernet Sauvignon at A was grafted onto 110 Richter for the Tukulu (sand clay) and onto 99 Richter for the Fernwood (sand), while those on the Oakleaf (sandy loam) at B, was grafted onto 110 Richter. Experimental plots, consisting of two adjacent rows, with 10 adjacent vines each, were selected on each soil type. Vines were spur-pruned annually to approximately 16 buds per meter cordon. Normal viticultural practices were applied at each site.
Dates of budbreak, flowering and harvest were recorded annually. Budbreak was noted when 50% of the buds had reached stage 4 and flowering at stage 23 of the modified E-L system (Coombe, 1995). Cane mass and grape yield were also determined. Grapes were harvested at optimal ripeness. For Sauvignon blanc this was considered to be at approximately 23°B, at a titratable acidity of 8 g/L and a pH of between 3.0 and 3.3, with Cabernet Sauvignon being harvested at approximately 24°B, with a pH of between 3.0 and 3.3. Experimental wines were prepared annually according to standard Nietvoorbij procedures, as summarized by Jolly *et al.* (2003). Wines were evaluated, six months after production, by 12 trained wine tasters. A ten-centimetre unstructured line scale was used and the judges were asked to rate wines for aroma components (undetectable to prominent), based on the standardized system of wine aroma terminology (Noble *et al.*, 1987). General quality was also rated on an unstructured line scale, from unacceptable to excellent.
RESULTS AND DISCUSSION

Climate
Climatic conditions remained reasonably consistent over the course of the three experimental seasons (data not shown). The general pattern, as determined during the 2002/2003 season, is shown in Table 1. In comparison to locality B, average maximum and minimum temperatures were, respectively, 0.95°C and 1.23°C higher at locality A. Number of hours with temperature > 30°C was also higher at A than at B, while number of hours with temperature < 5°C, was lower at A. It was, therefore, appreciably cooler at B than at A, largely because night temperatures were lower. Temperatures during the growing season (2010 degree-days) placed locality A in region IV (1945-2222 degree-days) of the

Winkler classification (Winkler *et al.*, 1974), while B (1915 degree-days) resided in the upper ranges of region III (1668-1944 degree-days).

Soils

In the case of the Sauvignon blanc vineyard at the warmer locality (Table 2), the Knersvlakte soil form (loamy sand) contained higher fractions of clay, silt and fine sand, in comparison to the Fernwood soil form (sand). This resulted in a higher water-holding capacity for the loamy sand (112 mm/m) than for the sandy soil (66 mm/m). For Sauvignon blanc at the cooler locality, the Fernwood (loamy sand) contained only 3.7% clay, in comparison to 21.0% for the Valsrivier (sand clay loam), while the former also contained a high fraction of stone and gravel (56.1%). Consequently, the water-holding capacity of the loamy sand (62 mm/m) was less than half that of the sand clay loam (157 mm/m). The Tukulu soil form (sand clay), planted to Cabernet Sauvignon at the warmer locality, contained 37.3% clay, in comparison to only 2.3% for the Fernwood soil form (sand). However, on account of a high fraction of stone and gravel (38.4%), in the case of the sand clay, water-holding capacities (81 mm/m for the sand clay and 72 mm/m for the sand) were comparable for the two soil forms. The Oakleaf soil form (sandy loam), planted to Cabernet Sauvignon at the cooler locality, contained 17.6% clay, in conjunction with a high fraction of stone and gravel (54.1%). The water-holding capacity of this soil (66 mm/m), was comparable to that of the Cabernet Sauvignon soils at the warmer locality.

Grapevine performance

Results, which are not reported in detail, are summarised below:

Phenology: Date of budbreak was usually one week earlier for the Sauvignon blanc than for the Cabernet Sauvignon. For a specific cultivar, however, date of budbreak appeared to be largely unaffected by climate and/or soil type. Time of flowering, generally during the first week of November, did not differ between cultivars. Over the course of the investigation period, date of harvest varied between 30th January and 12th February for Sauvignon blanc. During a specific season, however, all experimental Sauvignon vineyards ripened at the same time, irrespective of locality and soil form. In the case of Cabernet Sauvignon, date of harvest was earliest (end February) for the Tukulu (sand clay) from the warmer locality. The Fernwood (sand) from the warmer locality and the Oafleaf (sandy loam) from the cooler locality ripened one week and two weeks later, respectively.

Vegetative growth and grape yield: The Sauvignon blanc on the sandy soil (Fernwood) at the warmer locality grew more vigorously, resulting in a higher yield, in comparison to those on the loamy sand (Knersvlakte). This may have been on account of a better root distribution, in the case of the sandy soil (data not shown). For Sauvignon blanc at the cooler locality, vigour and grape yield was unaffected by the different soil forms. At the warmer locality, Cabernet Sauvignon on the sandy clay (Tukulu) grew less vigorously, thus also yielding less, than those on the sandy soil (Fernwood). This was ascribed to poor root distribution in the compact Tukulu soil, which was characterised by a high clay fraction (Table 2).

Plant water status: Leaf water potentials (measured between 12:00 and 14:00), pointed towards similar levels of water stress, for a specific cultivar at a specific locality. This suggested that the effect of different soil forms was eliminated by means of regular irrigation.

Wine Quality

Sauvignon blanc: All the Sauvignon blanc wines (Table 3) received a relatively high score for tropical character (pineapple, melon, banana, guava), this being in agreement with the fruity/tropical style expected for “warm climates” (Marais *et al.*, 1999). However, even though soil form did not affect wine style/overall quality significantly at the cooler locality, the wine from the loamy sand (Fernwood) was generally regarded as being more “typical”, and of superior quality, in comparison to the one from the sand clay loam (Valsrivier). Tropical character appeared to be identical for the two wines, but aroma intensity, fresh vegetative character (grass, green pepper, eucalyptus) and cooked vegetative character (green beans, asparagus, olive), tended to be higher for the one from the more sandy soil. The effect of soil form on wine style could thus still be detected, in spite of the vineyards being intensively irrigated. This result (superior quality for Sauvignon blanc from soils with lower clay contents), is in agreement with the experience of vintners in the Breede River Valley. (Robertson Wine Valley, Sauvignon blanc study group, unpublished data, 2004). The specific factors, causing this phenomenon, have not yet been identified. Where irrigation is scientifically scheduled, the effect of soil form is possibly diminished, but not entirely eliminated. Wines from the warmer locality received lower scores for aroma intensity, fresh vegetative character and overall quality, in comparison to those from the cooler locality. No differences could be detected between the wines from the warmer locality, thus being in contrast to results for the cooler locality.

Cabernet Sauvignon: Aroma intensity and overall wine quality were comparable for the wine from sand clay (Tukuku) at the warmer locality and the one from the sandy loam (Oakleaf) at the cooler locality (Table 4). In comparison to Sauvignon blanc, the quality of Cabernet Sauvignon, therefore, appeared to be affected to a lesser extent by a warmer climate. However, wine styles were widely divergent. The wine from the warmer locality exhibited a pronounced berry character, in comparison to a lower berry and a higher vegetative (grass, green pepper, hay/straw) character for the one from the cooler locality. The wine from the sandy soil at the warmer locality, received lower scores for aroma intensity, berry character and overall quality, in comparison to the one from the more clayey soil. As in the case of Sauvignon blanc from the cooler locality, the effect of soil form could not be entirely eliminated by means of regular irrigation.

CONCLUSIONS

Even though the Breede River Valley is generally regarded as being relatively warm, appreciable variations in meso-climate occur within the Region. At warmer locations aroma intensity is low for Sauvignon blanc, while style is not affected by different soil forms. Wines with a more pronounced Sauvignon blanc character can be produced at cooler locations, although different soil types may induce divergent styles. The quality of Cabernet Sauvignon appears to be affected to a lesser extent by a warmer climate. However, wines with widely divergent styles may be obtained under different climatic conditions. For Cabernet Sauvignon, soil type can also have a major effect on wine style, with aroma intensity being lower on sandy soils.

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TABLE 1
Climatic data for 2002/2003, as measured at two different localities in the Breede River Valley (mean values for period from 01/04/2002 to 31/03/2003).

Locality	Average Max. temperature (° C)	Average Min. temperature (° C)	Average Mean temperature (° C)	Temperature > 30 °C (number of hours)	Temperature < 5 ° C (number of hours)
A	24.97	10.66	17.34	499	398
B	24.02	9.43	16.35	377	491

TABLE 2
Soil particle size distribution (%), gravel content and water holding capacity for soils planted to Sauvignon blanc and Cabernet Sauvignon at different localities in the Breede River Valley (depth weighted means to a depth of 1000 mm).

Cultivar	Locality	Soil Form	Soil Texture	Clay [1] (< 0.002 mm)	Silt [1] (0.05–0.002 mm)	Fine sand [1] (0.25-0.05 mm)	Medium sand [1] (0.05-0.25 mm)	Coarse sand [1] (2.0-0.50 mm)	% Stone & Gravel (> 2.0 mm)	Water holding capacity (mm/m)
Sauvignon blanc	A (warmer)	Fernwood	Sand	3.9	4.2	30.2	52.7	9.0	0	66
		Knersvlakte	Loamy sand	5.4	7.6	44.5	29.3	13.2	13.9	112
	B (cooler)	Fernwood	Loamy sand	3.7	8.7	25.5	27.9	34.1	56.1	62
		Valsrivier	Sand clay loam	21.0	13.4	37.9	12.7	15.0	9.1	157
Cabernet Sauvignon	A (warmer)	Tukulu	Sand clay	37.3	4.2	33.1	16.3	9.2	38.4	81
		Fernwood	Sand	2.3	3.1	50.4	38.4	5.9	0	72
	B (cooler)	Oakleaf	Sandy loam	17.6	8.2	44.2	14.3	15.7	54.1	66

[1] Particle size analyses for soil fraction ≤ 2 mm, excluding gravel.

TABLE 3
Effects of soil and climate on the style of Sauvignon blanc wine from the Breede River Valley (mean values for three seasons: 2000/2001 to 2002/2003).

Locality	Soil type	Wine quality [1]				
		Aroma Intensity	**Fresh vegetative character [2]**	**Cooked vegetative character [3]**	**Tropical character [4]**	**Overall quality**
A (warmer)	Sand	5.40 a [5]	2.84 a	2.16 a	3.98 a	4.61 a
	Loamy sand	5.16 a	2.88 a	2.02 a	3.85 a	4.53 a
B (cooler)	Loamy sand	6.09 b	3.56 b	2.72 b	3.70 a	5.50 b
	Sand clay loam	5.64 ab	3.23 ab	2.20 ab	3.74 a	5.05 ab

[1] As evaluated by an experienced panel on a ten-centimetre unstructured line scale (undetectable/unacceptable = 0, prominent/excellent = 10).
[2] Herb, grass, green pepper, eucalyptus.
[3] Green beans, asparagus, olive, artichoke.
[4] Pineapple, melon, banana, guava.
[5] Different letters within the same column denote significant differences ($p \leq 0.05$).

TABLE 4
Effects of soil and climate on the style of Cabernet Sauvignon wine from the Breede River Valley (mean values for three seasons: 2000/2001 to 2002/2003).

Locality	Soil type	Wine quality [1]				
		Aroma Intensity	**Vegetative character [2]**	**Berry character [3]**	**Spicy character [4]**	**Overall quality**
A (warmer)	Sand clay	6.29 a [5]	3.12 ab	4.99 a	2.25 a	5.76 a
	Sand	5.27 b	2.97 a	3.73 b	1.83 a	4.51 b
B (cooler)	Sandy loam	5.94 a	3.65 b	4.28 b	1.88 a	5.29 ab

[1] As evaluated by an experienced panel on a ten-centimetre unstructured line scale (undetectable/unacceptable = 0, prominent/excellent = 10).
[2] Grass, green pepper, blue gum, hay/straw, tobacco.
[3] Blackberry, raspberry, strawberry, black currant.
[4] Liquorice, aniseed, black pepper, clove.
[5] Different letters within the same column denote significant differences ($p \leq 0.05$).