VITICULTURAL TERROIRS IN STELLENBOSCH, SOUTH AFRICA. II. THE INTERACTION OF CABERNET-SAUVIGNON AND SAUVIGNON BLANC WITH ENVIRONMENT

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Abstract

Aims: A terroir can be defined as a grouping of homogenous environmental units, or natural terroir units, based on the typicality of the products obtained. Terroir studies therefore require an investigation into the response of grapevines to the natural environment.

Methods and results: A network of plots of Sauvignon blanc and Cabernet Sauvignon were delimited in commercial vineyards in proximity to weather stations and their response monitored for a period of seven years. Regression tree methodology was used to determine the relative importance of the environmental and management related variables and to determine regression trees for each dependent variable. Excepting for scion clone, which had a high relative importance for bunch mass of Sauvignon blanc and yield to pruning mass index of Cabernet Sauvignon, no other non-environmental variable included in the analyses appeared to have a strong effect on grapevine performance and wine character. The performance of Cabernet-Sauvignon was related to the potassium content of the subsoil and climate (temperature and rainfall) of the season. The performance of Sauvignon blanc appeared to be related to soil texture, wind exposure and temperature of the site and season, both during the green berry growth stage and the month prior to ripening.

Conclusions: From the results presented, it appears that environmental parameters have an overriding effect on the performance of both Cabernet Sauvignon and Sauvignon blanc but that these two cultivars react differently to environmental stimuli.

Significance and impact of study: These results should contribute to the identification of viticultural terroirs with specific agronomic potential for Cabernet-Sauvignon and Sauvignon blanc.

Keywords: Sauvignon blanc, Cabernet-Sauvignon, grapes, wine, temperature, soil, wind, climate

Résumé

Objectifs : un terroir peut être défini comme un ensemble d'unités environnementales homogènes, ou unités naturelles de terroirs, sur la base de la typicité des produits qui y sont obtenus. Les études de terroirs requièrent donc une recherche spécifique concernant la réponse de la vigne à son environnement.

Méthodes et résultats : Un réseau de parcelles de Sauvignon blanc et de Cabernet-Sauvignon a été mis en place chez des vignerons, à proximité de stations météorologiques, et le comportement de la vigne y a fait l'objet de suivis pendant 7 années. La méthode des arbres de régression a été utilisée pour déterminer l'importance relative des variables liées à l'environnement et aux pratiques et élaborer des arbres de régression pour chaque variable dépendante. À l'exception de la variable « clone » qui semble jouer un rôle important sur la masse des grappes de Sauvignon blanc et sur l'indice de Ravaz du Cabernet-Sauvignon, aucune autre variable non-environnementale prise en compte dans l'analyse ne semble avoir d'effet significatif sur le comportement de la vigne et la typicité du vin. La performance du Cabernet-Sauvignon a pu être reliée à la teneur en potassium de la roche-mère et au climat (température et pluviométrie) de l'année. Quant au Sauvignon blanc les variables les plus influentes ont été la texture du sol, l'exposition au vent et la température du site ainsi que celle du millésime, aussi bien pendant la croissance herbacée de la baie que dans le mois précédant la maturation.

Conclusions : Les résultats de l'étude montrent que les paramètres environnementaux jouent un rôle prépondérant sur la performance du Cabernet Sauvignon et du Sauvignon blanc. Cependant, ces deux cépages réagissent différemment aux stimuli environnementaux.

Intérêt et impact de l'étude : Les résultats obtenus devraient contribuer à identifier des terroirs viticoles ayant un fort potentiel agronomique pour le CabernetSauvignon et du Sauvignon blanc.

Mots-clés : Sauvignon blanc, Cabernet-Sauvignon, raisins, vins, température, sol, vent, climat

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Abbreviations Irrigate = Dryland or irrigated; Rootstock = name; Clone = scion clone, Vine density = Number of vines per hectare; Canopy height = Height between cordon wire and top wire; Trellis system = Type of trellis system; Plant year = year in which planted; Aspect = Compass directions in degrees; Slope = Slope inclination in %; Altitude = Height above sea level (m); Dist_sea = Minimum distance from the coast (km); Flo_maxT = Mean maximum temperature for October and November (°C); Flo_minT = Mean minimum temperature for October and November (°C); Flo_meanT = Mean temperature for October and November (°C); Flo_rain = Rainfall for October and November (mm); Flo_WSgr4 = Number of hours with wind speed greater than 4 m.s^{-1} for October and November (hrs); MaxT = Mean maximum temperature during the 31 days prior to harvest (°C); MinT = Mean minimum temperature during the 31 days prior to harvest (°C); MeanT = Mean temperature during the 31 days prior to harvest (°C); GDD = Total growing degree-days during the 31 days prior to harvest; T2025 = Number of hours with a temperature between 20 °C and 25 °C during the 31 days prior to harvest; Tgr30 = Number of hours with a temperature higher than 30°C during the 31 days prior to harvest; Rad = Total radiation during the 31 days prior to harvest; Sun = Total sunshine hours during the 31 days prior to harvest; WS = Mean wind speed during the 31 days prior to harvest (m/s); WSgr4 = Number of hours with a wind speed greater than 4 m/s during the 31 days prior to harvest; Evap = Evapotranspiration during the 31 days prior to harvest (mm); Rain = Rainfall during the 31 days prior to harvest (mm); MinRH = Minimum relative humidity during the 31 days prior to harvest (%); MeanRH = Mean relative humidity 31 days prior to harvest (%); TVI = Thermal variability index (Gladstones, 1992); HI = Huglin Index (Huglin, 1986); Winkler = Winkler Index (Le Roux, 1974); DI = Dryness Index (Tonietto and Carbonneau, 2004); Soil pH = Depth weighted mean of the subsoil pH (0.3 m-1.0 m); Stone = Depth weighted mean of the % stones in the profile (0 m-1.0 m); Plow = Depth weighted mean of the subsoil phosphorous (mg/kg) (0.3 m-1.0 m); Klow = Depth weighted mean of the subsoil potassium (mg/kg) (0.3 m-1.0 m); s-value = Depth weighted mean of the S-Value (exchangeable cations) (cmol/kg) (0 m-1.0 m); Clay_low = Depth weighted mean of the subsoil clay content (%) (0.35 m-0.7 m) (Tesic, 2003); Clay = Depth weighted mean of the clay content (%) (0 m-1.0 m); Silt = Depth weighted mean of the silt content (%) (0 m-1.0 m); FiS = Depth weighted mean of the fine sand content (%) (0 m-1.0 m); MeS = Depth weighted mean of the medium sand content (%) (0 m-1.0 m); CoS = Depth weighted mean of the coarse sand content (%) (0 m-1.0 m); Soilprep = Observed depth of soil preparation; SI = Site index (Tesic *et al.*, 2002).

INTRODUCTION

A terroir can be defined as a grouping of homogenous environmental units, or natural terroir units, based on the typicality of the products obtained (Laville, 1993). It is, therefore, a representation of the agricultural aptitude of a site resulting from the interaction of its environmental features. These environmental features are climate (rainfall, relative humidity, air temperature, soil temperature, direction and intensity of dominant winds), topography (slope, exposition, sunlight exposure and landscape form) and soil (mineralogy, compaction, granulometry, soil water reserve, depth, and colour) (Laville, 1993). The terroir definition prescribes a biphasic study, namely (a) the characterisation of the environment and identification of natural terroir units taking all relevant natural factors into account, together with (b) the characterisation of the viticultural and oenological potential of these units over time (Morlat, 2001 ; Vaudour, 2003). The first part of such a study for the Stellenbosch Wine of Origin District has been described in a companion paper (Carey *et al.*, 2008).

Cabernet-Sauvignon and Sauvignon blanc have been the subject of a number of studies in South Africa (inter alia Archer and Strauss, 1989, Hunter *et al.*, 1991; Hunter *et al.*, 1995; Hunter and Ruffner, 1997, 2002; Marais *et al.*, 1999; Conradie *et al.*, 2002), but only those of Marais *et al.* (1999) and Conradie *et al.* (2002) have focused specifically on the interaction of *Vitis vinifera* (cv. Sauvignon blanc) with its growing environment. The significance of the viticultural environment for wine style and wine quality in South Africa has long been recognized (Theron, 1932; Le Roux, 1974; Saayman, 1977). This lead to the establishment of the Wine of Origin Scheme in 1973 (Burger and Saayman, 1981), creating the impetus for the present day terroir studies in South Africa, initiated by ARC Infruitec-Nietvoorbij. In 1995, a network of experimental plots was established in the Stellenbosch environs to aid in the identification of terroirs for viticulture.

Using these results, this paper describes and discusses the determination of the cultivar x terroir interaction.

MATERIALS AND METHODS

Study area and vineyard sites

The study was limited to the Stellenbosch Wine of Origin District, South Africa, situated at 34 °S, 19 °E

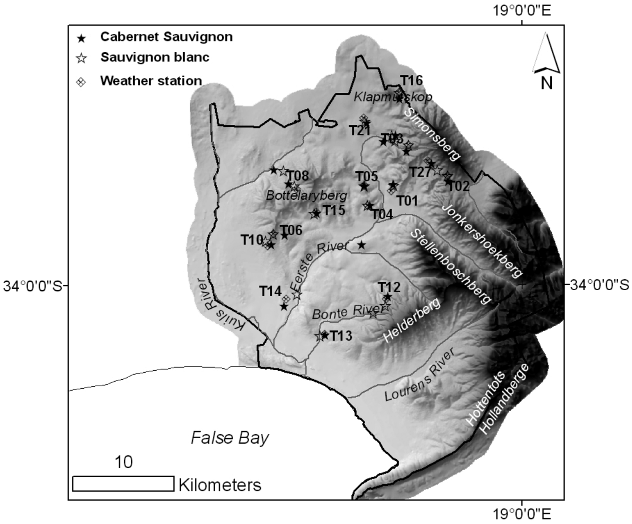

Figure 1 - The location of the Stellenbosch Wine of Origin District (solid black line) together with the positions of weather stations (labelled Tn) and experimental plots of *Vitis vinifera* L. cv. Cabernet-Sauvignon and Sauvignon blanc.

(figure 1). Twenty reference plots each of Cabernet-Sauvignon and Sauvignon blanc of ca. 30 vines per plot were delimited during 1995 in commercial vineyards for a study period of seven years (figure 1). Thirty of these experimental plots were within a radius of 1 km from a representative automatic weather station. Vine density, scion clone, rootstock, vine spacing, canopy height and irrigation practices were noted. Geographic co-ordinates, altitude, aspect and slope inclination were determined from 1:10 000 ortho-photos (Chief Directorate: Surveys and Mapping). The approximate minimum distance from the False Bay coast was determined in ESRI®ArcMap™ 8.2 and noted as distance from the coast.

Viticultural and oenological measurements

All vines were pruned to the norm of 16 buds per meter cordon within a four-week period. For each of these plots, the dates of budburst, flowering and berries harvest-ripe (Coombe, 1995) were recorded when 50 % of the monitored vines had reached the said stage. Pruning mass per meter cordon for 10 vines was determined. The canopy was evaluated at harvest using a score card adapted from Smart and Robinson (1991) and the yield per meter cordon for 10 vines was determined. A random standard sample of five bunches (Van Schalkwyk, 2004) was selected from amongst bunches that had been harvested per plot for microvinification. Bunch characteristics (number of berries per bunch, bunch mass, mass of 100 berries) were determined for these samples. Musts were microvinified according to standard procedures (ARC Infruitec-Nietvoorbij) and sensorially evaluated ca. 6 months after harvest according to appropriate aroma categories from the Wine Aroma Wheel (Noble *et al.*, 1987), using an unstructured line scale and an expert panel of between 12 and 14 judges. The wines were presented in one session per cultivar, with the two cultivars being presented to separate panels on consecutive days. Standard must and wine analyses were performed in a commercial laboratory.

Soil measurements

Soil profiles at each plot were examined in 2000 and described using the South African taxonomic system (Soil Classification Working Group, 1991). Standard soil chemical and physical analyses were performed in a commercial laboratory. On examination of the soil profiles, it was noted that, for most of the plots, grapevine roots only colonised the ploughed portion of the soil, and the depth of soil preparation was therefore assumed to be the effective soil depth.

Climatic measurements

A network of automatic weather stations (MCSystems) was established in 1995 (figure 1). Five of these weather stations were microclimatic and situated in the vineyard row while the remaining 11 were mesoclimatic and situated on open ground in the vicinity of vineyards. Data from mechanical weather stations (Agromet, ARC-ISCW) were used where available to complete the data set. For the automatic weather stations, the parameters of temperature, dry and wet bulb temperature or relative humidity, rainfall, radiation, sun duration, wind speed and wind direction were recorded every one-minute. These values were averaged or summed, depending on whether or not the parameter is cumulative in nature, for one-hour periods. The temperature sensors were housed in a Stevenson screen 1.2 m above the soil surface. The anemometer and pyranometer were situated at 2.0 m above the soil surface.

Mean monthly climatic data for automatic weather station T01 were used to compare the climate of each season during the seven-year study period.

Hourly climatic data were used to calculate a number of climatic variables. Mean maximum, mean minimum and mean temperature, number of hours with a wind speed greater than 4 m/s and rainfall were calculated for the period of October and November. Mean maximum, mean minimum and mean temperature, number of hours with temperature between 20 and 25 °C, number of hours with a wind speed greater than 4 m/s, maximum wind speed, mean wind speed, maximum, minimum and mean relative humidity, mean relative humidity at 15:00 SAST, radiation, hours of sunshine, growing degree days and evapotranspiration were calculated for the month before harvest for each of the plots. The month before harvest was selected for these calculations as a broad association between the average mean temperature during the final ripening month and wine style produced has previously been shown (Gladstones, 1992). In addition, the Huglin index (Huglin, 1986), Amerine and Winkler Growing Degree-day index, as adjusted for South Africa by Le Roux (1974), the dryness index (Tonietto, 1999 ; Tonietto and Carbonneau, 2004) and thermal variability index (Gladstones, 1992) were calculated.

Vineyard characteristics

Viticulture in South Africa is non-prescriptive and viticultural management strategies are thus diverse. The experimental plots were non-homogenous with respect to clone, rootstock, vine spacing, trellis system, irrigation and age. The variables irrigation, rootstock, scion clone, vine density, canopy height, trellis system and year of planting were therefore included in the analyses as management related variables (treated as independent) in order to test the relative importance of their influence.

Missing data

Missing data resulted from accidental pruning or harvesting of experimental plots by producers, technical faults in automatic weather stations and/or lack of knowledge of producers regarding rootstock or scion clones.

Statistical analyses

Regression tree analyses (Breiman *et al.*, 1984) were used to analyse the complete data set. A variable importance factor in terms of its effect on the response variable was derived once the tree was built. This variable importance was calculated based on the number of times the variable was used as splitting variable and how well it separated low values from high values (M Kidd, personal communication, 2004).

A method called bagging (bootstrapping) was used for determination of variable importance. This is a resampling technique where trees are built repeatedly on samples drawn randomly (with replacement) from the original sample. The relative importance for each variable was then calculated as the average variable importance for the individual trees (M Kidd, personal communication, 2004).

Each data point was plotted as a member of a terminal node of the pertinent regression tree in order to determine whether a climatic effect was predominantly seasonal or whether site climate also played a role.

RESULTS AND DISCUSSION

Climate of the vintage

The seven-year study period included vintages with diverse climatic conditions (figure 2). The 1996/1997 season was, for example, noticeably cooler than the seven-year mean throughout the season (figure 2a), while in the 1999/2000 season, a heat wave was experienced during December, resulting in a mean temperature that was 3.0 °C warmer than the seven-year mean (figure 2a). The 2001/2002 season had higher rainfall than the seven-year mean during the growing period (figure 2b). Season was therefore expected to strongly affect the performance of Cabernet-Sauvignon and Sauvignon blanc. This seasonal variability emphasizes the need for multiple seasons of measurement, ranging from 3-years to 7-years (Deloire *et al.*, 2005) so as to obtain more robust results.

Parameters affecting the performance of Cabernet-Sauvignon and Sauvignon blanc

The relative importance of the four most important environment or management related variables are given for each dependent variable of Cabernet-Sauvignon and Sauvignon blanc in tables 1 and 2. Only « independent » variables with a relative importance of greater than 70 % were considered to have any real importance in determining the dependent variable, unless they had a very narrow confidence interval (M Kidd, personal communication, 2004).

As the plot network was heterogeneous with respect to plant material and viticultural management practices, it was necessary to test whether these differences outweighed the effect of the environment on the performance of the two cultivars under investigation.

Contribution of genotype to viticultural and oenological performance

Three rootstocks were represented in this study, namely Richter 99, Richter 110 and 101-14 Mgt. Although these rootstocks are known to have different effects on grapevine growth and production (Pongrácz, 1983), the relative importance of rootstock did not exceed 9.4 % for Cabernet-Sauvignon or 28.1 % for Sauvignon blanc.

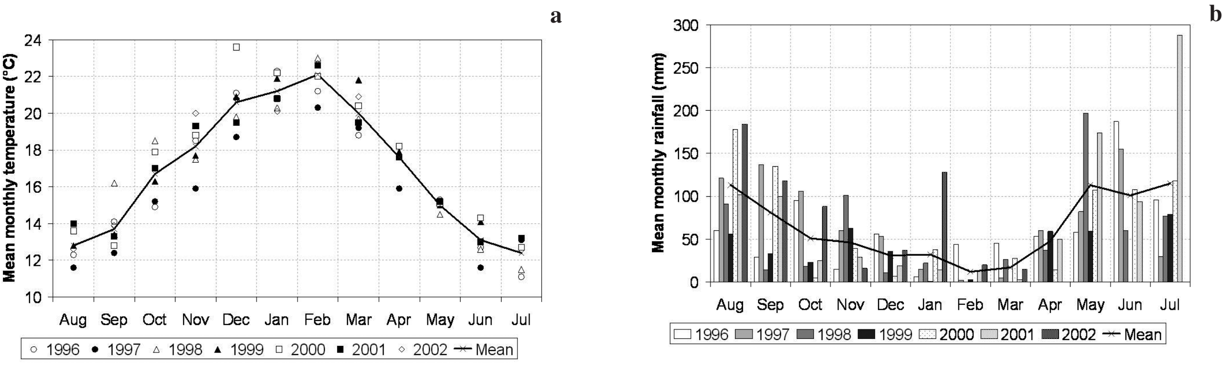

Figure 2 - Mean monthly temperature (a) and rainfall (b) for each of the seven seasons of the study, compared to the seven-year mean measured at the automatic weather station at the Nietvoorbij campus of ARC Infruitec-Nietvoorbij (T01). The date in the legend indicates the harvest season, for example, 1996 represents the period from August 1995 to July 1996.

This may suggest that the rootstocks were chosen correctly for the respective soil types. Scion clone, however, had a greater relative importance with respect to distinguishing between viticultural and oenological performance. A relative importance of 81.8 % was obtained for bunch mass of Sauvignon blanc (table 2) and 85.1 % for the yield to pruning mass ratio of Cabernet-Sauvignon (table 1). A relative importance of less than 70 % was obtained for all other dependent variables.

Contribution of viticultural management to viticultural and oenological performance

The age of vines did not exceed a relative importance of 70 % for any of the dependent variables of Cabernet-Sauvignon or Sauvignon blanc, but was selected as a splitting variable in the final regression tree for the canopy index of Sauvignon blanc. Similarly, vine spacing did not exceed a relative importance of 70 %, although it was selected as a splitting variable for bunch mass and total estimated dry matter production (« puissance », Deloire *et al.*, 2002) of Sauvignon blanc, and must soluble solids of Cabernet-Sauvignon. Canopy height, trellis system and irrigation did not have a relative importance greater than 70 % for any dependent variable, nor were they

Table 1 - Relative importance of the four most important variables affecting the performance of Cabernet-Sauvignon in the Stellenbosch Wine of Origin District, South Africa

Dependent variable	Environmental and management related variables (relative importance)
Phenology	
Date of flowering	**MeanT**[1] (90.8%), **GDD** (89.7%), **MinT** (77.1%), MaxT (53.5%)
Date of harvest	**Rad** (97.1%), Evap (72.2%), Sun (69.9%), GDD (50.9%)
Growth and yield	
Cane mass (kg/m)	**MaxT**[*] (68.5%), MeanT (52.5%), **clone** (32.7%), Flo_meanT (30.9%)
Canopy Index	Vine density (59.4%), **CoS** (51.7%), **Flo_meanT** (41.4%), Flo_maxT (34.1%)
Yield (kg/m cordon)	**Alt** (60.1%), FiS (59.6%), **Clone** (47.8%), aspect (45.5%)
No of berries per bunch	GDD (76.9%), **MeanT** (75.7%), Tgr30 (69.8%), T2025 (56.5%)
Bunch mass (g)	**FiS** (48.7%), **Dist_sea** (40.9%), Evap (38.2%), Slope (34.8%)
Berry mass (g)	Tgr30 (58.6%), GDD (57.1%), **T2025** (56.6%), Rad (54.3%)
Yield: pruning mass ratio	**Clone** (85.1%), Soil pH (54.5%), dist_sea (50.5%), **Aspect** (43.2%)
Total estimated dry matter production[2]	**FiS** (61.1%), S-Val (59.9%), Plant year (52.8%), MaxT (48.8%)
Must analyses	
Total soluble solids (°Balling)	**Evap** (56.5%), Vine density (34.3%), **S-value** (31.9%), clay (31.1%)
Total titratable acidity (g/L tartaric acid)	**Evap** (73.7%), Rad (58.6%), Tgr30 (44.8%), T2025 (41.3%)
pH	**Evap** (78.2%), Rad (59.3%), GDD (51.8%), T2025 (41.4%)
Maturity index[3]	**Evap** (53.5%), vine density (42.0%), Rad (39.5%), Tgr30 (38.4%)
Wine analyses	
Specific gravity	**Alt** (71.5%), **Klow** (56.8%), Trellis system (44.3%), Flo_WSgr4 (42.4%)
Alcohol (vol %)	**Evap** (63.5%), Rad (42.5%), MeanT (34.6%), **Clone** (34.4%)
Extract (g/L)	**Klow** (53.9%), soil pH (47.9%), Plow (40.0%), **clay** (33.5%)
ph	**Klow** (94.6%), Flo_WSgr4 (69.4%), **Alt** (65.8%), Slope (26.6%)
Total titratable acidity (g/L tartaric acid)	MeanT (65.7%), GDD (54.4%), **Flo_maxT** (52.7%), MinT (44.5%)
Volatile acidity (g/L)	**GDD** (66.4%), evap (60.1%), rad (57.6%), **Flo_meanT** (51.0%)
Wine sensory analyses	
Colour	**Clone** (37.3%), Flo_minT (31.0%), vine density (29.7%), **slope** (27.4%)
Astringency	**DI** (35.3%), Rad (31.5%), **dist_sea** (31.3%), alt (30.7%)
Acid	**Flo_meanT** (71.2%), Flo_maxT (62.6%), **MeanT** (55.9%), GDD (46.9%)
Fullness	**Clay** (51.7%), **S_val** (50.8%), clay_low (34.6%), **MaxT** (31.7%)
Berry	**Rain** (66.2%), MeanT (51.1%), GDD (49.7%), **Flo_meanT** (44.1%)
Vegetative	**Rain** (57.9%), MeanT (46.3%), GDD (39.6%), **Rad** (30.9%)
Floral	**Flo_rain** (56.1%), **MinT** (45.3%), **Flo_maxT** (34.8%), MeanT (29.8%)
Spicy	**Flo_rain** (69.9%), Alt (44.2%), **Flo_meanT** (32.0%), **Flo_minT** (31.8%)

[1]Bold type represents predictor variables selected for final regression trees; [2]puissance (Deloire *et al.*, 2002)
[3](MustTSS x 10)/MustTTA

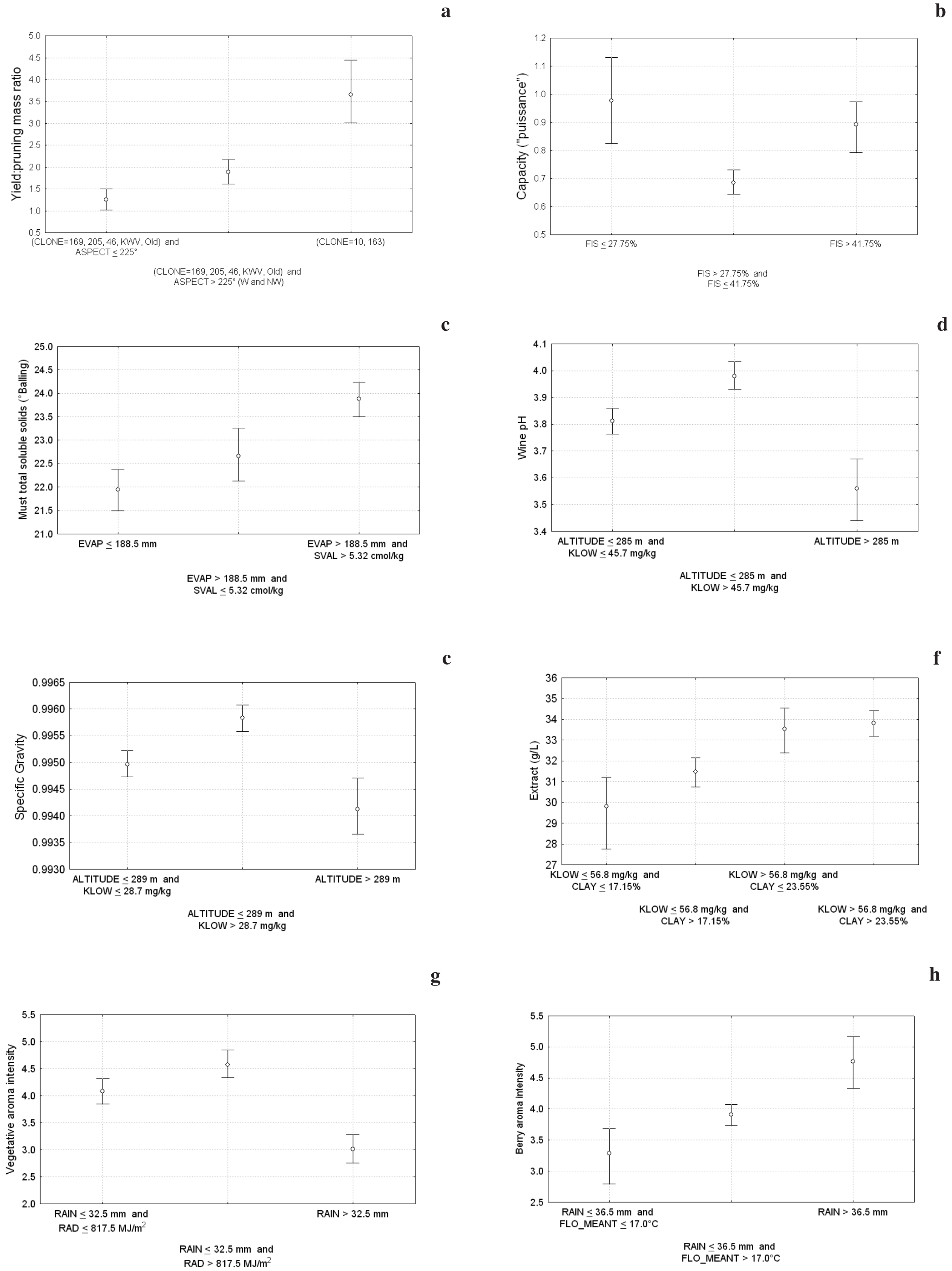

Figure 3 - Bootstrap mean values for terminal nodes of final regression trees of selected viticultural and oenological variables of Cabernet Sauvignon, Stellenbosch. Vertical bars denote 0.95 bootstrap confidence intervals.

Table 2 - Relative importance of the four most important variables affecting the performance of Sauvignon blanc in the Stellenbosch Wine of Origin District, South Africa

Dependent variable	Environmental and management related variables (relative importance)
Phenology	
Date of flowering	**Flo_MaxT**[1] (97.3%), Flo_MeanT (96.9%), Winkler (75.2%), HI (67.9%)
Date of harvest	**Flo_MaxT** (90.7%), Flo_MeanT (89.6%), Winkler (60.8%), **Rad** (53.2%)
Growth and yield	
Cane mass (kg/m)	**Clone** (43.8%), clay_low (41.0%), stone (40.3%), **clay** (33.0%)
Canopy Index	**MeanT** (49.6%), **plant year** (46.6%), MaxT (46.6%), Flo_meanT (42.2%)
Yield (kg/m cordon)	**Flo_WSgr4** (82.3%), WS (68.8%), **WSgr4**(62.3%), Soil_prep (30.3%)
No of berries per bunch	Flo_maxT (68.9%), **Flo_rain** (61.2%), **rad** (55.2%), Flo_meanT (42.2%)
Bunch mass (g)	**Clone** (81.8%), **vine density** (39.4%), K Low (37.3%), soil_prep (33.7%)
Berry mass (g)	Flo_maxT (89.5%), **Flo_rain** (73.6%), **Flo_meanT** (70.5%), rad (65.1%)
Yield: pruning mass ratio	Slope (73.5%), **dist_sea** (62.8%), clay (62.6%), **clay_low** (55.2%)
Total estimated dry matter production[2]	**WSgr4** (79.9%), **vine density** (61.7%), **WS** (61.0%), Flo_WSgr4 (51.9%)
Must analyses	
Total soluble solids (°Balling)	**Rain** (43.7%), **Flo_maxT** (39.6%), Flo_maxT (35.9%), Silt (28.95)
Total titratable acidity (g/L tartaric acid)	**GDD** (39.1%), **rad** (38.7%), **MeanT** (35.6%), Flo_rain (31.7%)
pH	**Plow** (32.6%), S-val (31.1%), **dist_sea** (30.5%), Alt (28.1%)
Maturity index[3]	**Flo_rain** (47.1%), S-val (35.0%), rad (32.6%), **clay-low** (25.3%)
Wine analyses	
Specific gravity	**Slope** (59.8%), dist_sea (57.8%), **clay_low** (51.2%), alt (42.3%)
Alcohol (vol %)	**Rain** (60.6%), **SI** (40.0%), Flo_meanT (31.9%), Flo_maxT (30.6%)
Extract (g/L)	**Klow** (34.3%), **S-val** (32.2%), Tgr30 (30.3%), Silt (30.1%)
pH	**MinT** (62.0%), MeanT (44.9%), Silt (42.0%), plant-year (41.6%)
Total titratable acidity (g/L tartaric acid)	**MeanT** (73.7%), **GDD** (61.3%), **MinT** (55.7%), MaxT (48.5%)
Volatile acidity (g/L)	**MeanT** (62.7%), Tgr30 (56.7%), **Flo_rain** (56.0%), MaxT (55.2%)
Wine sensory analyses	
Acid	**Flo_minT**[*] (86.1%), Flo_meanT (82.4%), Flo_maxT (62.3%), **Tgr30** (35.8%)
Fullness	Flo_meanT (52.8%), **Flo_minT** (49.6%), **Flo_maxT** (44.3%), MeanT (43.3%)
Fresh vegetative	**Flo_minT** (76.8%), Flo_meanT (62.0%), Flo_maxT (53.3%), **Stone** (25.7%)
Cooked vegetative	Trellis system (44.2%), **Clone** 937.5%), **Alt** (28.4%), FiS (25.5%)
Dried vegetative	**Dist_sea** (51.1%), **Flo_meanT** (42.6%), Flo_rain (39.5%), Flo_MaxT (37.8%)
Tropical fruit	**Flo_meanT** (70.9%), **Flo_minT** (70.7%), Flo_maxT (58.0%), **dist_sea** (29.5%)
Spicy	**Flo_meanT** (79.5%), Flo_minT (70.6%), Flo_maxT (55.6%), **Rad** (29.5%)
Caramel	**Rain** (42.7%), Flo_minT (30.3%), **Flo_rain** (30.0%), Flo_meanT (29.6%)

[1] Bold type represents predictor variables selected for final regression trees

[2] « Puissance » (Deloire *et al.*, 2002)

[3] (MustTSS x 10)/MustTTA

selected as splitting variables in any of the regression trees.

Factors affecting the performance of Cabernet-Sauvignon

Regression tree analyses indicated that the phenology, growth, yield, berry composition and wine related parameters of Cabernet-Sauvignon were affected by the climate of the season, soil and topographic related site characteristics and scion clone.

The phenology of Cabernet-Sauvignon was predominantly affected by seasonal climate with little to no contribution of site (table 1). The timing of the variables having the highest relative importance did not necessarily coincide with the phenological event in question, e.g. the mean temperature during the month prior to ripening had a relative importance of 90.8 % for flowering of Cabernet-Sauvignon. This can be ascribed to the significant correlation between the phenological stages of budburst, flowering and harvest ($p \leq 0.05$).

A previous statistical study on the same set of dependent variables showed that yield:pruning mass ratio, capacity (or estimated total dry mass, Deloire *et al.*, 2002), must titratable acidity and soluble solids, wine pH, titratable acidity and density and the sensory score for wine astringency of Cabernet-Sauvignon, were the variables with the greatest discriminatory value between sites (Carey *et al.*, 2003).

The yield:pruning mass ratio, an indication of the sink:source ratio, was significantly higher for scion clones CS 10 and CS 163 (figure 3). This appeared to be due to the effect of clone on yield (table 1), with the terminal node with the highest yield to pruning mass ratio being associated with significantly higher yield per meter cordon (data not shown). The capacity of the grapevines, on the other hand, was related to soil texture (table 1 and figure 3), as represented by the percentage of the fine sand fraction present in the soil profile to a depth of 100 cm. The parent material contributing to the soils would be expected to affect the particle size distribution, although this may not always represent the underlying parent material (Conradie *et al.*, 2002). In general, though, it would be expected that soils originating from phyllitic shale (Tygerberg formation of the Malmesbury group) would weather into predominantly fine particles, followed by hornfels and finally granite (Conradie *et al.*, 2002). The group with the lowest percentage fine sand particles was represented by sites with granitic parent material. These sites were also associated with the highest medium and coarse sand contents, low silt content and variable but generally low clay content. The second group, with intermediate fine sand contents, represented the majority of experimental sites. The third group, with the highest percentage fine sand, was represented by sites with deep, highly weathered apedal soils. This relationship of fine sand content may, however, be disputable as the fine sand content had a similar relative importance to the S-value (total cation content) variable (both below 70 %) and may well have effectively masked the S-value from inclusion within the final regression tree structure.

Must analyses were predominantly affected by the climate of the season (table 1), although these effects did not appear to have a high importance. Some vineyards were not able to ripen their fruit to the desired level of technological ripeness (ca. 24 °B), resulting in significant differences ($p \leq 0.05$) between plots in total soluble solid content at harvest (results not presented). This may be due partially to the presence of leafroll infection, which is widely spread in all wine producing areas of South Africa (Pietersen, 2004). Leafroll infection holds consequences for the performance of grapevines, especially yield and berry composition (Goheen and Cook, 1959; Over de Linden and Chamberlain, 1970) and infected vineyards become more sensitive to abiotic stress situations (Carstens, 2002). However, not all sites included in the terminal nodes with low bootstrap mean total soluble solids (22.0°B) had visual symptoms of leaf roll and some of those that did have visual symptoms were included in the terminal nodes with higher bootstrap mean total soluble solids (22.7°B and 23.9°B). Grapes with low total soluble solids were generally left on the vines until the first autumn rains. As autumn approaches, evaporation decreases. As a result, the vineyards that could not fully ripen their grapes were associated with lower evaporation rates during the month before harvest (table 1 and figure 3c). The ability of a site to ripen grapes when evaporation rates were high was related to the depth-weighted mean S-value of the soil (table 1 and figure 3c) in the final regression tree, although the relative importance of this variable was negligible. The S-value of soils reflects the sum of exchangeable Ca, Mg, Na and K (Soil Classification Working Group, 1991) and has been found to be higher for soils derived from Malmesbury shale (Conradie *et al.*, 2002). S-value is also dependent on the clay content of the soil and shall thus represent, to a certain extent, the soil water-holding capacity (D. Saayman, personal communication,, 2004). The determination of soil water-holding capacity did not fall within the confines of this investigation but deserves further study due to its particular relevance for terroir studies (Saayman and Kleynhans, 1978; Seguin, 1986; Morlat *et al.*, 1992; Choné *et al.*, 2001; Van Leeuwen *et al.*, 2003). The more fertile soils (possibly with a better soil water-holding capacity) were associated with the terminal node having the highest total soluble solid content. The strong relationship between must titratable acidity and evapotranspiration during the month before ripening (table 1) appeared to be predominantly related to season. The terminal node with the highest mean total titratable acidity (8.9 g/L), and concomitantly the lowest values for evapotranspiration, included predominantly data points from the 1997 season. It must be remembered that evapotranspiration is a function of inter alia solar radiation, air temperature, vapour pressure and wind speed. The 1997 season was characterized by markedly cool conditions (figure 2a), and the effects of temperature on acidity have been well documented (Ruffner, 1982; Jackson and Lombard, 1993; Terrier and Romieu, 2001). The node with lower titratable acidity was associated with higher evapotranspiration rates, which in turn are associated with higher air temperature and wind speed. A study in the Loire Valley (Barbeau *et al.*, 2003) has shown that higher wind speeds in the period prior to harvest reduced must acidity, and especially malic acid levels for red cultivars. The inclusion of evapotranspiration as a predictor variable for must acidity in this study, may therefore be related to temperature, particularly at the microclimatic level, and wind effects.

Wine pH appeared to be strongly affected by site, with potassium content in the sub-soil, number of hours with a wind speed greater than 4 m/s during October and November (the green stage of berry growth) and altitude being the environmental variables having the highest relative importance in the case of Cabernet-Sauvignon (table 1 and figure 3d). Although the number of hours with a wind speed greater than 4 m/s was not selected for the final regression tree, a relationship between wind exposure and wine pH has been shown on the same data set (Carey *et al.*, 2003). It appeared that increased wind exposure was associated with wines having a higher wine pH. Berry potassium content has been related to pH values in a number of studies (Hale, 1977; Boulton, 1980; Mpelasoka *et al.*, 2003). Although increased potassium levels in berries of grapevines that have been exposed to wind have been recorded (Kliewer and Gates, 1987), the mechanism causing this increase has not been clearly identified. Freeman *et al.* (1982) have suggested that any factor that reduces the photosynthetic activity of leaves will result in increased potassium accumulation in berries, with implications for wine pH. Such factors are wind exposure, water stress and excessive shading in the canopy. Rogiers *et al.* (2006) hypothesized that potassium accumulation in grape berries may assist in the accumulation of sugars, due to its being the main osmotically active cation and its probable contribution to the maintenance of an osmotic potential gradient between the leaves and the berries. This would imply that under conditions of reduced photosythesis and thus sugar loading in the berry, there would be an increased loading of potassium to facilitate the accumulation of sugars. The relationship between photosynthesis and potassium loading in the berry has, however, not been found under all experimental conditions (Etchebarne and Deloire, personal communication, 2008). It would appear from their studies that final concentrations of potassium in the grape berry are most closely linked to plant water status. The results of the regression tree analyses suggest that the potassium content of the subsoil had a strong effect on wine pH (table 1 and figure 3d). The uptake of potassium ions by plant roots is determined by the plant available potassium levels of the soil, but also by the distribution and activity of grapevine roots, relative concentrations of other cations, rootstock and scion combination, berry growth, canopy microclimate and management practices (Mpelasoka *et al.*, 2003). Up to half of the potassium in ripe berries may be located in the skin and at full ripeness skin tissue has a high leaching rate (Iland and Coombe, 1988). As the Cabernet-Sauvignon was fermented on skins, a higher wine pH is probably associated with increased potassium content in the skins of the berries. Potassium availability to the vine depends on inter alia soil characteristics related to the nature and degree of weathering of parent material (lit. cited in Mpelasoka *et al.*, 2003) and soil mineralogy (Wooldridge, 1988). Granitic soils generally have the highest potassium content (Wooldridge, 1988; Van Schoor, 2001), which is unbuffered and favours rapid plant uptake (Wooldridge, 1988), followed by shales, while sandstones are generally poorly supplied with plant mineral nutrients (Wooldridge, 1988; Van Schoor, 2001). Conradie *et al.* (2002) found, however, that potassium levels of subsoils in the Stellenbosch area could not be related to underlying geological formations, probably as a result of management practices, including mineral fertilisation (vid. Seguin, 1986). Altitudes of greater than 285 m were associated with the lowest wine pH values. Altitude has been associated with lower mean temperatures and higher kaolinite clay fractions in the South Western Cape, with implications for vegetative growth, fresh vegetative character and wine quality of Sauvignon blanc (Van Schoor, 2001), suggesting a possible combined contribution of temperature and soil origin to wine pH values in this study.

The titratable acidity of the Cabernet-Sauvignon wine, on the other hand, was predominantly related to the climate, and especially temperature during the green berry growth stage (table 1). Mean maximum temperature values for October and November that were greater that 22.6 °C were associated with lower wine TTA values (results not presented). Lower acidity values in association with higher temperatures have been well documented (Ruffner, 1982; Terrier and Romieu, 2001). This is mainly related to degradation or compartmentalization of malic acid, which starts prior to the ripening phase under warm conditions.

For Cabernet-Sauvignon, wine specific gravity, a measure of the concentration of matter, had a similar relationship to the environment as wine pH (table 1), but was more sensitive to subsoil potassium concentrations, with the split occurring at a value of 28.7 mg/kg (figure 3e). Wine extract, too, was related to potassium content of the subsoil with the terminal split occurring at 56.8 mg/kg (table 1). Higher values of subsoil K were associated with higher values for wine extract. Within each of these nodes, the depth-weighted clay content caused a further split, higher values being associated with wines with higher extract values (figure 3f).

No environmental or management variables exceeded a relative importance of 70 % for the sensory characteristics of Cabernet-Sauvignon (table 1), but climate related variables appeared dominant. Plotting the individual data points as members of the terminal nodes for each sensory variable indicated that the climate effect was predominantly seasonal. Site related variables were included in the final regression trees, but they cannot be considered unequivocal. The lack of a clear site effect may be due to the short period (ca. six-months) between fermentation and sensory analysis as young wines can be dominated by common fermentation compounds, complicating the sensory analysis. Nonetheless, it appears from the results of the regression tree analyses that rain during the month before ripening (berry and vegetative associated aromas) and the green growth period of the berry (floral and spicy associated aromas) played a role in determining the final wine aroma composition (table 1).

The cultivar typical aroma of Cabernet-Sauvignon can be described as having a fruit flavour of blackcurrants and green bell peppers (Robinson, 1996). A total of 48 aroma-active compounds have been distinguished in Cabernet-Sauvignon wines (Kotseridis and Baumes, 2000). The vegetative notes (including descriptors such as bell pepper, herbaceous, freshly cut green grass, eucalyptus, mint, artichoke, hay and tobacco) (Noble *et al.*, 1987) could be attributed to aldehydes such as decanal and (E, Z) - nona - 2, 6 - dienal (Kotseridis and Baumes, 2000) as well as the well-documented methoxypyrazines (Roujou de Boubée *et al.*, 2000). In this study, in contrast to Roujou de Boubée *et al.* (2000), seasons or sites with a higher rainfall resulted in wines with a lower vegetative aroma intensity. The lower vegetative aroma intensity may be attributable to an overall low aroma intensity (not determined), but it may also be due to differential canopy management in an attempt to ensure more open canopies in rainy conditions. The relationship between higher levels of radiation during the month before harvest and increased intensity of vegetative aroma characteristics also contrasts with existing literature on the effects of radiation on methoxypyrazine levels (Marais *et al.*, 1999). The radiation values in this study refer to global radiation, which may have contributed to higher photosynthetic levels, increased vegetative growth and thus denser canopies. This variable does not have a high value of relative importance (table 1) and its effect is not clear. It is also not known to what extent aldehydes, with a potentially different climatic response to that of methoxypyrazines, contribute to the vegetative aroma characteristics of Cabernet-Sauvignon under South African conditions and deserves further study.

In contrast, Cabernet-Sauvignon wines from seasons or sites with a higher rainfall during the month before harvest were described as having more intense berry aroma characteristics. Various studies (literature cited in Noble *et al.*, 1995) have suggested that berry aromas are associated with soils having a lower water-holding capacity. The authors postulated that this was related to reduced canopy growth on sand or gravelly soils resulting in a more open canopy and thus photodegradation of methoxypyrazines. No control was exercised over the canopy management practices of the producers in the study reported in this paper and it is common practice to break out leaves following rainfall during the period preceding harvest in order to limit the development of bunch rot. Higher rainfall during the month before harvest may therefore well have contributed indirectly to more open canopies via intervention of the vineyard manager. In seasons with normal rainfall, warmer temperatures during October and November were associated with more intense berry aromas.

Fullness on mouth-feel was affected by clay content and S-value of the soil (table 1), with wines from shale-derived soils, which have a higher clay content and higher S-values, being fuller on mouth-feel. Although previous studies had suggested that the sensory score for astringency was a discriminating variable (Carey *et al.*, 2003), the relative importance of the predictor variables did not differ significantly and the resulting regression tree did not distinguish between groups (data not shown).

Factors affecting the performance of Sauvignon blanc

The performance of Sauvignon blanc was mainly affected by the climate of the season, site climate, genotype, management practices, topography and soil related factors. Discriminant analyses on the same data set (Carey *et al.*, 2003) indicated that pruning mass, yield, bunch mass, ratio of pruning mass to yield and cooked vegetative aroma intensity (asparagus/green beans/artichokes) were the dependent variables having the greatest discriminatory value between sites.

The phenology of Sauvignon blanc, similarly to Cabernet-Sauvignon, was more affected by the climate of the season than site. The phenological stages that were monitored were highly correlated with one another and could be explained by the mean maximum temperature during the months of October and November (table 2). Radiation contributed to the time of harvest. Sites that received a higher global radiation during the month prior to harvest were harvested earlier.

There was no clear discrimination between environmental or management related variables with respect to relative importance for pruning mass or canopy index (table 2), but scion clone and depth-weighted mean percentage of clay in the soil profile were selected for the final regression tree for pruning mass. A heavy-textured soil (clay>25 %), generally due to a high clay content in the sub-soil, was associated with reduced vegetative growth for selected clones. This may have been due to reduced root growth resulting from excessively compact sub-soils as above-ground growth generally directly reflects root volume (Archer and Strauss, 1991). In non-irrigated situations, however, a lower pruning mass would also be expected on sandy soils as a result of the lower soil water holding capacity, and increased water deficit. In seasons without excessive heat, age of the vines determined the canopy index. Less dense canopies were associated with older vineyards (planted prior to 1984).

Yield per meter cordon was positively related to exposure of a locality to wind during the green berry growth stage (October and November) and during the month prior to harvest (table 2), but this relationship contradicted existing literature (figure 4a). Protection of grapevines from wind has been associated with increased yield (Dry *et al.*, 1988; Hamilton, 1989; Dry and Botting, 1993; Bettiga *et al.*, 1997), but in the Stellenbosch Wine of Origin District, localities exposed for longer to wind velocities exceeding 4 m/s appeared to be associated with increased yield (figure 4a). This increased yield was not clearly associated with either number of berries per bunch or berry mass. Wind is one of the climatic variables having the highest degree of spatial variability (Dumas *et al.*, 1997; Carey, 2001) and in a region such as the Stellenbosch Wine of Origin District where wind is a common climatic phenomenon during the ripening period, site differences would appear to be stronger than seasonal differences. The higher yield was significantly correlated with higher bunch mass ($r = 0.58$, $p \leq 0.05$), which could be attributed to greater number of berries per bunch ($r = 0.59$, $p \leq 0.05$), although neither of these variables was associated with exposure to wind in the regression tree analyses (table 2). Some studies have attributed the increased yield for protected vines to increased shoot numbers per vine (Bettiga *et al.*, 1997), which can be associated with increased pruning mass. A one-way ANOVA of the pruning mass values associated with the three terminal nodes of the regression tree for yield shown in figure 4a showed no significant difference between groups (data not shown). None of the plots studied in this investigation were exposed to excessively strong winds that resulted in marked loss of shoots, physical damage or noticeably poor growth and berry set. Sheltered vines have been shown by Bettiga *et al.* (1997) to have larger primary and secondary leaves. This would contribute to increased shading in the canopy. Increased exposure to wind, with increased leaf flustering and smaller leaves, associated with wind exposure, can be expected to contribute to increased sunlight penetration in the canopy. This may have facilitated increased initiation of inflorescence primordia and translocation of carbohydrates to bunches. Midday leaf water potential values have been shown to be more negative for sheltered vines than exposed vines (Freeman *et al.*, 1982; Bettiga *et al.*, 1997). Therefore, stomatal closure, due to exposure to wind in excess of 4 m/s (Campbell-Clause, 1998), may have limited water deficit at exposed plots, also contributing to higher yield. These aspects deserve further study as it was not clear what mechanism may have contributed to the increased yield.

The yield to pruning mass ratio (figure 4b) is a measure of the sink to source relationship in the grapevine. The majority of plots in the investigation were represented by the terminal node with the lowest mean value for yield:pruning mass ratio in figure 4b. The terminal node with the highest mean value for yield to pruning mass ratio, determined by proximity to False Bay, was represented by plots with predominantly low pruning mass (figure 4b). These vineyards are characterized by relatively sandy soils with a fairly high Na content on the coastal plain. The moist air from the sea that moves inland in the afternoon will be expected to have a fairly high salt content, which may also restrict vegetative growth. The terminal node that is characterized by plots that are situated further inland and having a depth-weighted clay content in the subsoil of greater than 37.4 % (figure 4b), has a yield to pruning mass ratio that is predominantly affected by the yield of the vineyards, which in all cases is greater than 2 kg/m cordon. The dense, highly structured subsoil of these plots is expected to warm more slowly in spring, resulting in a slower initial growth phase and more open canopies during inflorescence initiation.

The total estimated dry matter production (Deloire *et al.*, 2002) or capacity of the Sauvignon blanc vineyards was predominantly affected by exposure to wind in excess of 4 m/s, apparently via the positive effect on yield, although increased vine density did contribute to reducing the capacity of vineyards in exposed situations (table 2 and figure 4c).

Plotting individual data points as members of terminal nodes indicated that must total soluble solids and titratable acidity were affected by the climate of the season, while must pH was related to site characteristics (table 2). There was, however, no environmental or management related

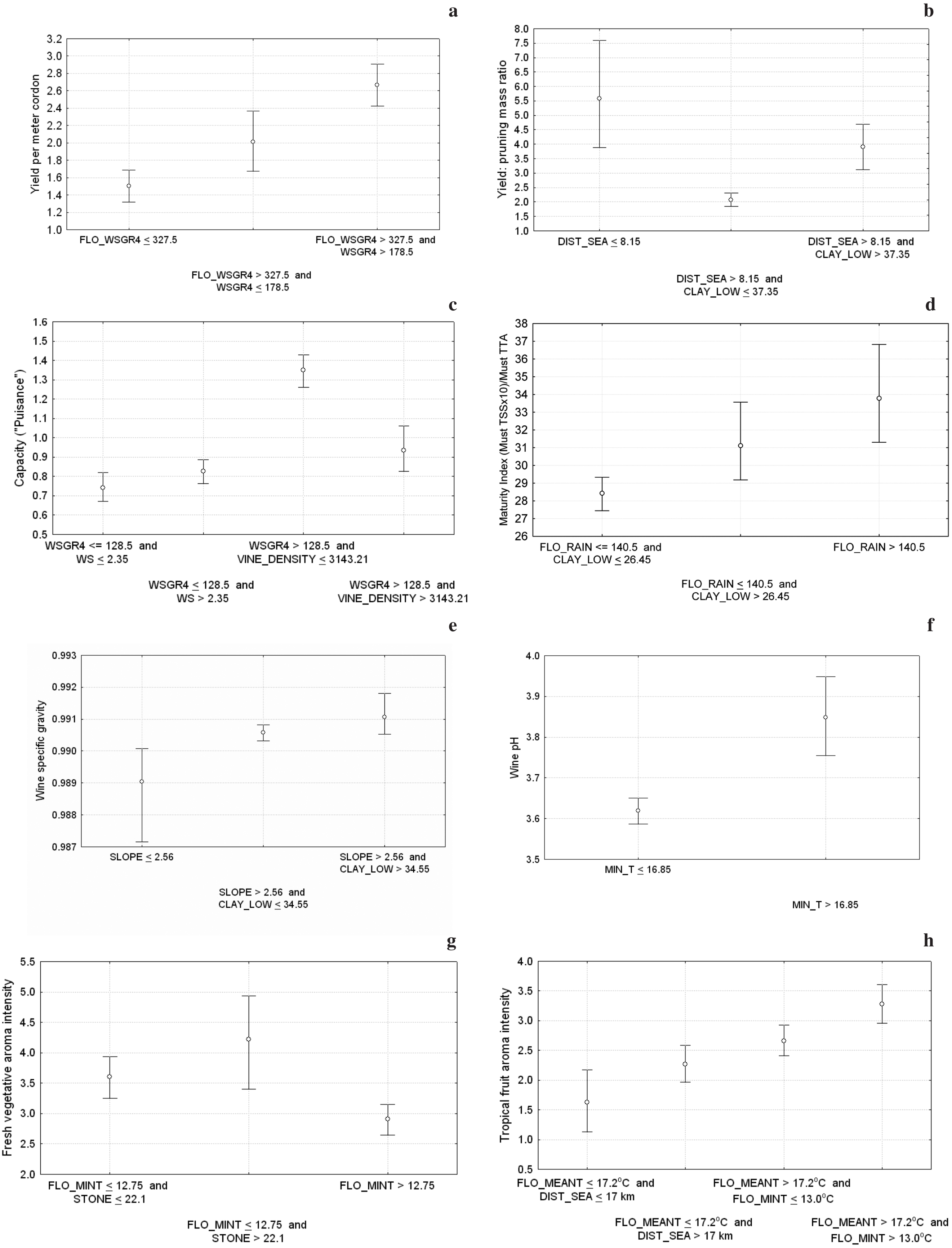

Figure 4 - Bootstrap mean values for terminal nodes of final regression trees of selected viticultural and oenological variables of Sauvignon blanc, Stellenbosch. Vertical bars denote 0.95 bootstrap confidence intervals.

variable that had a high relative importance or that was clearly associated with these parameters. Although the maturity index (table 2 and figure 4d) did not differ significantly between terminal nodes, plotting the must total soluble solids against the must titratable acidity for each group suggested that the terminal node with the lowest bootstrap mean for the maturity index (figure 4d) had the more ideal berry composition (degrees balling ca. 23 °B, titratable acidity between 8 and 9 g/L, pH values of below 3.5). This terminal node represented the majority of plots included in the investigation. The other two terminal nodes with less ideal composition were represented either by seasons with high rainfall during October and November, or plots with a clayey sub-soil.

The alcohol content of the Sauvignon blanc wines, volatile acidity and total titratable acidity were mainly related to climate (table 2). The specific gravity of the wine appeared to be determined by position in the landscape. The lowest specific gravity was associated with wine from vineyards on the coastal plain (as represented by low slope inclination) (figure 4e). These vineyards are associated with sandy soils and an influx of moist sea air in the afternoon. Wine extract, similarly to Cabernet-Sauvignon, was related to the potassium content of the subsoil (table 2), although the relative importance of this variable was not high. It appeared that soils with higher levels of exchangeable cations, together with potassium, lead to wines with higher extract (results not presented). As mentioned previously, both the potassium content of the subsoil and the S-value (sum of exchangeable cations) can be related to parent material, with granite and shale derived soils having the highest values. Wines originating from vineyards on granite and shale-derived soils would therefore be expected to have a higher extract than those on sandstones.

Sauvignon blanc wine pH values, although affected to a certain extent by site, did not have a similar relationship to the environment as Cabernet-Sauvignon. The minimum temperature during the month prior to harvest appeared to best separate plots with respect to wine pH for Sauvignon blanc (table 2, figure 4f). Jackson and Lombard (1993) suggested that low night temperatures are necessary when day temperatures are warm for lower pH values and higher natural acidity. This is substantiated in this investigation as those plots having the highest minimum temperature prior to harvest had the highest wine pH (figure 4f). Wine pH was also positively correlated with pruning mass ($r = 0.41$, $p \leq 0.05$). This relationship is expected due to the well-known negative effects of canopy shading (Smart and Robinson, 1991), which appears to be related to increased potassium content of grapes from shaded canopies (Morrison and Noble, 1990). The temperature effect on titratable acidity was also clear (table 2). The highest temperatures were associated with the lowest values of titratable acidity (data not shown).

Climate, and especially temperature, during the green stage of berry growth appeared to affect the sensory characteristics of Sauvignon blanc in the Stellenbosch Wine of Origin District (table 2). Plotting the individual data points as members of terminal nodes of the regression trees for each of the sensory variables indicated that the effects were predominantly seasonal, although the effect of site climate was not negated. The characteristic green bell-pepper and grassy aromas related to the 2-methoxy-3-isobutylpyrazine (Allen *et al.*,, 1991) were more intense for sites or seasons with lower pre-véraison minimum temperatures (figure 4g). The effect of temperature during ripening on methoxypyrazine concentrations is well documented (Allen *et al.*, 1988; Allen and Lacey, 1993; Marais *et al.*, 1999). To our knowledge, no data on the effect of temperature during the pre-véraison period on methoxypyrazine concentrations has been published. From data presented by Lacey *et al.* (1991) it appears that grapes from « cooler » regions and or seasons have higher levels of methoxypyrazines at comparably low total soluble solids values, which suggests that conditions during the pre-ripening period may influence the methoxypyrazine content prior to degradation as well as the degree of loss during ripening. No data was, however, presented on the climatic conditions during this pre-véraison phase. For a more acceptable wine, it is necessary that the typical grass-like aroma is balanced by other herbaceous and fruity aromas (Marais, 1994). The cooked vegetative aroma characteristics (asparagus/green bean) are typical of 2-methoxy-3-isopropylpyrazine (Allen *et al.*, 1988). In this investigation no environmental or management related variable had a high relative importance with respect to these aroma characteristics

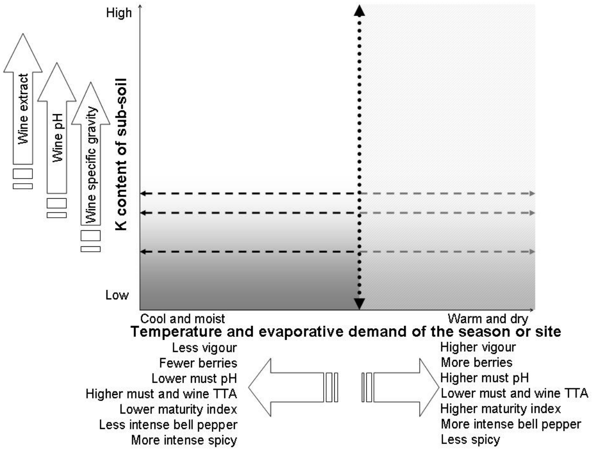

Figure 5 - Summary of soil and temperature effects on the performance of Cabernet Sauvignon in the Stellenbosch Wine of Origin District.

(table 2). Although scion clone and altitude were selected as splitting variables, their scores for relative importance were low (table 2). The tropical fruit (figure 4h) and spicy (results not presented) aromatic intensity increased with increasing temperature during the pre-véraison period. Fruity and tropical aromas appear to be related to monoterpenes and C13-norisoprenoids (Sefton *et al.*, 1994). Marais *et al.* (1999) found that the tropical/fruity style of Sauvignon blanc in South Africa was characteristic of warmer regions. This correlated with the higher relative concentration of total acid-released monoterpenes and C13-norisoprenoids. The concentration of these compounds has also been found to increase with ripeness and increased sunlight penetration in the canopy (Marais *et al.*, 1999).

CONCLUSIONS

It would seem that environmental parameters have an overriding effect on the performance of both Cabernet-Sauvignon and Sauvignon blanc, but that these two cultivars react differently to environmental stimuli (figures 5 and 6).

It appears that the potassium (K) content of the subsoil, possibly related to geological parent material, affected the performance of Cabernet-Sauvignon in the Stellenbosch Wine of Origin district (figure 5). Soils derived from sandstone would be expected to have a reduced ability to ripen fruit. The wines from these vineyards would potentially have a lower wine pH, specific gravity and extract due to the lower expected K content. Grapes from vineyards on shale derived soils would be expected to ripen fully and result in wines that are fuller on mouth-feel. Granite derived soils on the other hand may result in Cabernet-Sauvignon wines with a higher pH, specific gravity and extract due to the higher expected K content. It is, however, not possible to negate the contribution of fertilisation in the above relationship. Although the K content of the subsoil was highlighted in this study, the soils described above would also be expected to result in different water supply to vineyards through the season.

The climate of the season appeared to have a very strong influence on the aroma characteristics of Cabernet-Sauvignon. Warmer sites during years with normal rainfall can be expected to result in more intense berry aroma characteristics.

The performance of Sauvignon blanc appeared to be related to soil texture, wind exposure and temperature, both during the green berry growth stage and the month prior to ripening (summarised in figure 6). The clay content of the subsoil could be related to pruning mass, yield:pruning mass ratio and maturity index. Vineyards on soils with a high clay content in the subsoil can be associated with less vigorous growth but a less ideal must composition (total soluble solids and total titratable acidity). Contrary to expectation, increased exposure to wind in the early part of the season was associated with higher yield. Lower minimum temperatures during the month prior to ripening ensured lower wine pH values. Lower minimum temperatures prior to véraison were associated with more intense bell-pepper and grassy aroma characteristics in the wines. Warmer sites and seasons were related to increased intensities of tropical fruit and spicy notes in the wines.

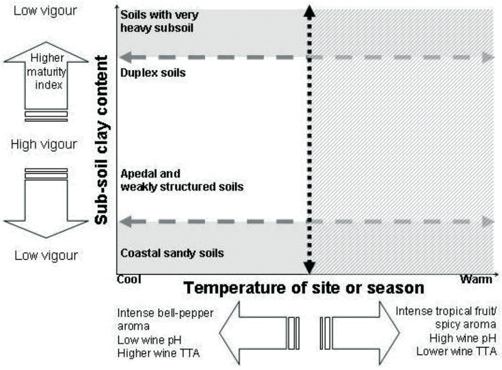

Figure 6 - Summary of soil and temperature effects on the performance of Sauvignon blanc in the Stellenbosch Wine of Origin District.

The environmental effects on the performance of Cabernet-Sauvignon and Sauvignon blanc in the Stellenbosch Wine of Origin District suggest that it will be possible to identify viticultural terroirs with specific agronomic potential for these two cultivars.

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