

Relationship Between Microclimatic Data, Aroma Component Concentrations and Wine Quality Parameters in the Prediction of Sauvignon blanc Wine Quality

J. Marais¹, F. Calitz² and P. D. Haasbroek³

1) ARC Infruitec-Nietvoorbij, Private Bag X5026, 7599 Stellenbosch, South Africa

2) ARC Biometry Unit, Private Bag X5013, 7599 Stellenbosch, South Africa

3) ARC Agromet, Private Bag X5013, 7599 Stellenbosch, South Africa

Submitted for publication: September 2000

Accepted for publication: April 2001

Key words: Microclimate, temperature, radiation, Sauvignon blanc quality, prediction model

Sauvignon blanc grape chemical and wine sensory data, as well as meteorological data (temperature and visible light radiation), collected in three climatically different wine regions in South Africa over three seasons and from two different canopy treatments were statistically analysed. A model for the prediction and/or definition of Sauvignon blanc wine quality was developed. The model utilises above- and within-canopy radiation and can explain 68.8% of the variation in the cultivar-typical vegetative/asparagus/green pepper intensity of Sauvignon blanc wine. Other significant correlations, e.g. between temperature and monoterpenes concentrations, were also obtained. Further research is necessary to test and refine this model for application under different environmental conditions.

Over many years research has been aimed at developing a simple model or recipe that could define and predict wine quality. Examples are sugar/acid ratio ($^{\circ}\text{B}/\text{TTA}$) (Du Plessis & Van Rooyen, 1982), the glycosyl-glucose (G-G) assay (Francis *et al.*, 1998) and the red wine colour index (Holgate, 2000). Such a model should also be useful as a method to compensate the grape producer according to grape quality. The aim further is that the model should incorporate parameters that are easily measurable under field conditions, instead of parameters such as aroma impact volatiles, the quantification of which is dependent on complicated and expensive gas chromatographic and mass spectrometric analyses. Due to the complexity of factors affecting grape and wine composition and quality, attempts to date have achieved varying degrees of success and a foolproof, simple model still has to be developed. Nevertheless, earlier attempts were valuable and all contribute something to the eventual solution of this problem.

Significant correlations between microclimatic parameters and wine sensory characteristics were reported earlier (Noble, Elliot-Fisk & Allen, 1995). Models using light radiation in the prediction of photosynthesis under field conditions, were also developed (Blackburn & Proctor, 1983; Goudriaan, 1986; Spitters, 1986; Haasbroek, Myburgh & Hunter, 1997). Photosynthesis is dependent on light radiation and temperature and is indirectly an important factor in grape composition development.

The approach in this study was to investigate the possible use of microclimatic parameters as a quality predictor, which can be easily measured over the whole grape-ripening period. The rate of enzymatic and chemical reactions in grapes, in terms of development and/or degradation of components, is dependent mainly on temperature and light radiation. Therefore these two climatic parameters were used as variables. Canopy density, which is a function of different climatic and viticultural factors, largely determines the effects of temperature and light radiation.

The purpose of this study was to correlate microclimatic data (temperature and radiation) with aroma component concentrations and wine quality parameters of Sauvignon blanc and to develop a model for predicting wine quality.

MATERIALS AND METHODS

Grapes, regions and seasons

Vitis vinifera L. cv. Sauvignon blanc grapes, grown in three climatically different regions, namely Robertson (Region IV, 1945 – 2222 degree days), Stellenbosch (Region III, 1668 – 1944 degree days) and Elgin (Region II, 1389 – 1667 degree days) (Le Roux, 1974), were used. A single canopy manipulation treatment, which altered microclimate in a natural way to obtain a higher degree of shading, was applied in each region (Archer & Strauss, 1989; Marais, Hunter & Haasbroek, 1999). Control vines were not manipulated. Three replications, consisting of 15 vines per replica, were used. The general viticultural practices followed were described by Marais *et al.* (1999). Grapes were obtained over three seasons, namely 1997, 1998 and 1999. Results of the 1997 and 1998 seasons were published by Marais *et al.* (1999) and trials during the 1999 season were a repetition of the first two seasons.

Grape samples (whole bunches, 2kg per sample) were collected weekly at random from each treatment and replicate over three weeks between approximately 16 $^{\circ}\text{B}$ (close to véraison) and 21 $^{\circ}\text{B}$ (ripeness). Grapes were harvested at ripeness (fourth ripening stage) for wine production, following standard Nietvoorbij practices for small-scale white wine production (Marais *et al.*, 1999).

Meso- and microclimatic measurements

MCS data loggers, which continually measured temperature and visible light radiation (300-1200nm) over the whole ripening period on an hourly basis, were installed within selected vine canopies in the vicinity of the clusters, as well as above the canopies. Each radiation sensor consisted of 10 individual sensors, fitted in parallel onto a metre-long rod, thus giving a more

reliable average reading within the canopy (Marais *et al.*, 1996; 1999). These measurements were done in each experimental unit.

Aroma component analyses

Grape samples from each treatment, region, season and replicate were analysed for free and bound monoterpenes and bound C₁₃-norisoprenoids by gas chromatography, and for 2-methoxy-3-isobutylpyrazine (ibMP) by gas chromatography / mass spectrometry (Marais *et al.*, 1996; 1999).

Sensory analysis

Wines of each treatment, region, season and replicate were sensorially evaluated for fruitiness and vegetative/asparagus/green pepper intensities by a panel of six experienced judges. A line method was used, i.e. evaluating the intensity of each characteristic by making a mark on an unstructured, straight 100 mm line (Marais *et al.*, 1999).

Statistical procedures

Seventy-two independent data sets consisted of three seasons, three localities, two canopy treatments and four ripening stages. Only 70 data sets were used, due to two missing plots. A 15-vine plot was considered as an experimental unit. For each experimental unit the microclimatic measurements, such as the mean maximum, mean minimum and average temperatures during a ripening week, were calculated and served as independent variables. The average light radiations above and within the canopies were also recorded as independent variables. The grape and wine measurements (averages of three replicates), such as aroma volatiles (monoterpenes, norisoprenoids and ibMP) and sensory data (fruitiness intensity and vegetative/asparagus/green pepper intensity) were recorded as dependent variables.

Pearson's correlation coefficients were calculated between the above-mentioned independent and dependent variables and scatter plots were examined for trends.

After examining the scatter plots, it was clear that the radiation variable showed a non-linear trend. Therefore three additional terms were added (i.e. the squares of the above- and within-canopy light radiation and the interaction between them) before the data were subjected to the stepwise regression procedures. For each dependent variable a stepwise regression was performed with a specified significance level of at least 5% for inclusion in the models, using SAS (Version 6.12) statistical software (SAS, 1990).

For the above-mentioned analyses, the data were handled in two ways. Firstly, all the data were statistically processed. Secondly, the data obtained at ripeness (fourth ripening stage) only were statistically processed, since wines were produced from grapes at this stage.

RESULTS AND DISCUSSION

The final models produced by the stepwise regression procedures are given in Table 1 and Figures 1 to 3 for the complete data set, and in Table 2 and Figures 4 to 6 for the data of harvest week four only. These coefficients correspond to significant correlations between dependent and independent variables (data not shown). The figures presented were selected with the main purpose of this study in mind, i.e. to predict wine quality from easily-measurable microclimatic parameters. Although ibMP was significantly described by the interaction of above- and within-canopy radiation, only 43.4% of the variation could be explained by the model (Table 1, Fig. 1). For fruitiness intensity 33.3% of the variation was explained by maximum temperature and the above-canopy radiation (Table 1, Fig. 2). The vegetative/asparagus/green pepper intensity (complete data set) showed the best coefficient of determination, i.e. $R^2 = 68.8\%$ (Table 1, Fig. 3). The above-canopy radiation showed a greater effect than the within-canopy radiation.

TABLE 1

Coefficients of independent variables selected for model and standard errors. Models fitted to all the data (N=70).

Variable	Intercept	T min.	T max.	T aver.	A	W	AxW	A ²	W ²	R ²
Monot	65.4387 ±8.0075	—	—	-2.3810 ±0.3752	—	—	—	—	—	37.2% sl<0.01
Noris	37.8475 ±5.9782	—	—	—	-0.5634 ±0.2537	—	—	—	—	6.8% sl=0.03
ibMP	91.8313 ±17.5359	—	—	—	-2.8195 ±0.7455	-14.8243 ±3.9360	0.5092 ±0.1616	—	—	43.4% sl<0.01
Fi	21.9055 ±10.4858	—	-1.0191 ±0.4318	—	2.1351 ±0.3767	—	—	—	—	33.3% sl<0.01
Vagp	265.119 ±29.648	—	—	—	-15.6791 ±2.6458	-8.3895 2.9499	—	0.3043 ±0.0590	0.5505 ±0.2492	68.8% sl<0.01

Monot	=	Total free monoterpenes (relative concentration)
Noris	=	Total bound monoterpenes and C ₁₃ -norisoprenoids (relative concentration)
ibMP	=	2-Methoxy-3-isobutylpyrazine concentration (ng/L)
Fi	=	Fruitiness intensity (%)
Vagp	=	Vegetative/asparagus/green pepper intensity (%)
A	=	Visible light radiation above the canopy (MJ)
W	=	Visible light radiation within the canopy (MJ)
T min.	=	Minimum temperature (°C)
T max.	=	Maximum temperature (°C)
T aver.	=	Average temperature (°C)
—	=	Not selected

TABLE 2

Coefficients of independent variables selected for model and standard errors. Models fitted to the data from harvest week four only (N=18).

Variable	Intercept	T min.	T max.	T aver.	A	W	AxW	A ²	W ²	R ²
Monot	66.5851 ±8.3672	—	-1.7250 ±0.2792	—	—	—	—	—	—	70.5% sl<0.01
Noris	—	—	—	—	—	—	—	—	—	—
ibMP	146.6720 ±55.4550	—	—	—	-11.9510 ±5.1776	—	—	0.2516 ±0.1180	—	40.8% sl=0.02
Fi	6.7709 ±16.2588	—	—	—	1.5152 ±0.6995	—	—	—	—	22.7% sl=0.046
Vagp	313.451 ±82.2622	—	—	—	-22.3616 ±7.6806	—	—	0.4499 ±0.1750	—	65.0% sl<0.01

- Monot = Total free monoterpenes (relative concentration)
 Noris = Total bound monoterpenes and C₁₃-norisoprenoids (relative concentration)
 ibMP = 2-Methoxy-3-isobutylpyrazine concentration (ng/L)
 Fi = Fruitiness intensity (%)
 Vagp = Vegetative/asparagus/green pepper intensity (%)
 A = Visible light radiation above the canopy (MJ)
 W = Visible light radiation within the canopy (MJ)
 T min. = Minimum temperature (°C)
 T max. = Maximum temperature (°C)
 T aver. = Average temperature (°C)
 — = Not selected

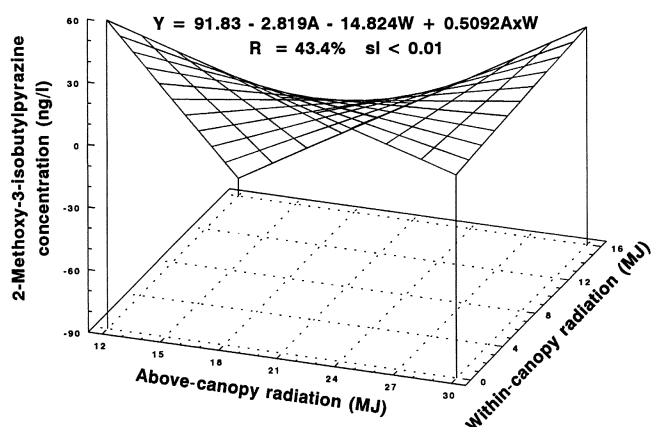


FIGURE 1

Effect of above-canopy (A) and within-canopy (W) radiation (between véraison and ripeness) on 2-methoxy-3-isobutylpyrazine concentration in Sauvignon blanc grapes.

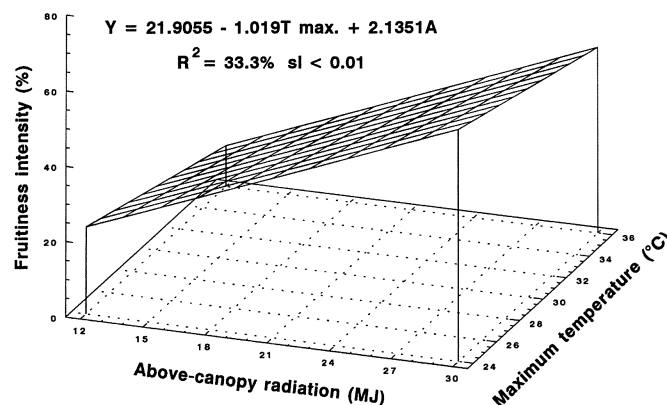


FIGURE 2

Effect of above-canopy (A) radiation and average maximum temperature (T max.) (between véraison and ripeness) on the fruitiness intensity of Sauvignon blanc wine.

tion. The higher the average above-canopy radiation, the lower the vegetative/asparagus/green pepper intensity of the wine (Fig. 3). This is in agreement with data presented by Marais *et al.* (1999). Although natural shading plays an extremely important role in Sauvignon blanc quality development (Marais *et al.*, 1999), models developed separately for the shaded and control treatment data were more or less the same as for the full data set and are therefore not reported.

Models arising from the data of ripening week four (harvest time) only are presented in Table 2. As much as 70.5% of the vari-

ation in monoterpene levels was explained by the average maximum temperature for the week in which the grape samples were taken. Monoterpenes may contribute to the flower-like nuances of Sauvignon blanc wine, but are probably less important than the cultivar-typical methoxypyrazines. The negative coefficient indicated that the higher the maximum temperature, the lower the monoterpene concentrations in the grapes, which is in agreement with results reported by Marais *et al.* (1999). There was not enough evidence, i.e. no variables were selected, to fit a model on the norisoprenoids in the grapes. 2-Methoxy-3-isobutylpyrazine,

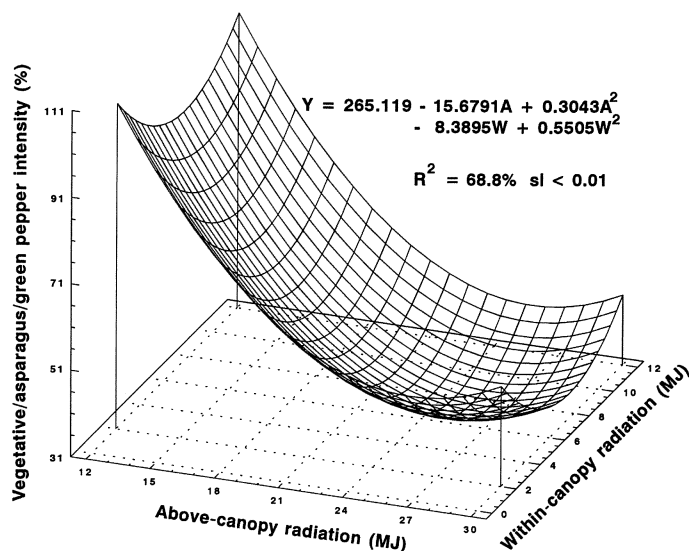


FIGURE 3

Effect of above-canopy (A) and within-canopy (W) radiation (between véraison and ripeness) on the vegetative/asparagus/green pepper intensity of Sauvignon blanc wine.

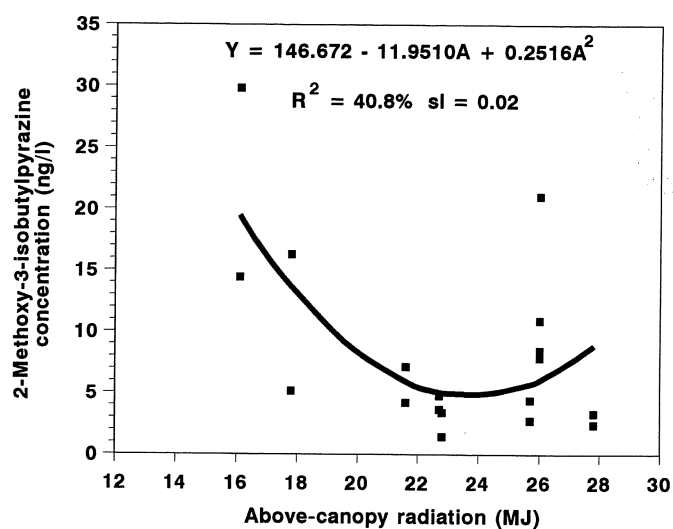


FIGURE 4

Effect of above-canopy (A) radiation at harvest (week 4) on 2-methoxy-3-isobutylpyrazine concentration in Sauvignon blanc grapes.

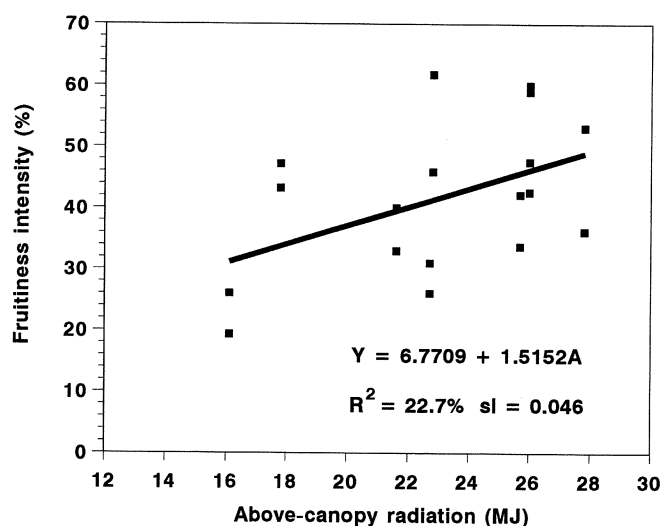


FIGURE 5

Effect of above-canopy (A) radiation at harvest (week 4) on fruitiness intensity of Sauvignon blanc wine.

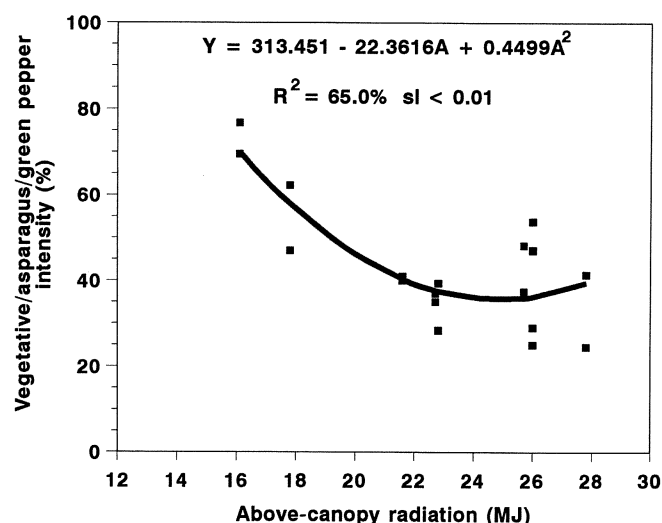


FIGURE 6

Effect of above-canopy (A) radiation at harvest (week 4) on vegetative/asparagus/green pepper intensity of Sauvignon blanc wine.

fruitiness intensity and vegetative/asparagus/green pepper intensity showed a significant response to the above-canopy radiation only (Figs. 4, 5 and 6, respectively). Again the vegetative/asparagus/green pepper intensity variation was best explained by a quadratic response of above-canopy radiation with 65.0%, and a minimum turning point of 24.9% for the above-canopy radiation. In spite of the fact that only 18 data points were applied for ripening week four, results obtained for vegetative/asparagus/green pepper intensity (65.0%, Table 2) were close to those of the full data set (68.8%, Table 1).

CONCLUSIONS

There is a significant relationship between gas chromatographically-analysed grape aroma components, sensorially-evaluated wine quality parameters and microclimatic data. Models are presented, one of which can predict Sauvignon blanc wine quality (cultivar-typical vegetative/asparagus/green pepper intensity) from above- and within-canopy radiation data, collected over grape ripening, with a fairly high degree of accuracy. It is therefore possible to predict wine quality from easily-measurable microclimatic data. The results of this investigation were

obtained under specific South African conditions and it is not claimed that they are valid under all conditions. Nevertheless, they can be considered as a contribution towards wine quality prediction. Future research is necessary to test and refine this model for application under different environmental conditions.

LITERATURE CITED

- Archer, E. & Strauss, H.C., 1989. Effect of shading on the performance of *Vitis vinifera* L. cv. Cabernet Sauvignon. S. Afr. J. Enol. Vitic. 10, 74-76.
- Blackburn, W.J. & Proctor, J.T.A., 1983. Technical note. Estimating photosynthetically active radiation from measured solar irradiance. Solar Energy 31, 233-234.
- Du Plessis, C.S. & Van Rooyen, P.C., 1982. Grape maturity and wine quality. S. Afr. J. Enol. Vitic. 3, 41-45.
- Francis, I.L., Iland, P.G., Cynkar, W.U., Kwiatkowski, M., Williams, P.J., Armstrong, H., Botting, D.G., Gawe, R. & Ryan, C., 1998. Assessing wine quality with the G-G assay. In: Blair, R.J., Sas, A.N., Hayes, P.F. & Hoj, P.B., (eds.). Proc. 10th Aust. Wine Ind. Tech. Conf., 2-5 August 1998, Sydney, Australia. pp. 104-108.
- Goudriaan, J., 1986. A simple and fast numerical method for the computation of daily totals of crop photosynthesis. Agric. For. Meteorol. 38, 249-254.
- Haasbroek, P.D., Myburgh, J. & Hunter, J.J., 1997. Modelling sunlight interception and photosynthetic activity – correlation with field data. Poster. 21st Annual SASEV Congress, 27-28 November 1997, Cape Town, South Africa.
- Holgate, A., 2000. Berry colour index assay – application and interpretation of the assay as an objective measure of red wine grape quality in a commercial vineyard. Proc. 5th Int. Symp. Cool Climate Vitic. & Enol., 16-20 January 2000, Melbourne, Australia. In press.
- Le Roux, E.G., 1974. 'n Klimaatsindeling van die Suidwes-Kaaplandse wynbougebiede. M.Sc. Thesis, University of Stellenbosch, Stellenbosch, South Africa.
- Marais, J., Hunter, J.J. & Haasbroek, P.D., 1999. Effect of canopy microclimate, season and region on Sauvignon blanc grape composition and wine quality. S. Afr. J. Enol. Vitic. 20, 19-30.
- Marais, J., Hunter, J.J., Haasbroek, P.D. & Augustyn, O.P.H., 1996. Effect of canopy microclimate on Sauvignon blanc grape composition. In: Stockley, C.S., Sas, A.N., Johnstone, R.S. & Lee, T.H. (eds.). Proc. 9th Aust. Wine Ind. Tech. Conf., 16-19 July 1995, Adelaide, Australia. pp. 72-77.
- Noble, A.C., Elliot-Fisk, D.L., & Allen, M.S., 1995. Vegetative flavor and methoxypyrazines in Cabernet Sauvignon. In: Roussef, R.L. & Leahy, M.M. (eds.). Fruit flavors, Biogenesis, Characterization and Authentication. ACS Symposium. Series 596, 22-27 August 1993, Chicago, Illinois, USA. pp. 226-234.
- SAS. 1990. SAS/Stat User's Guide. Version 6, 4th Edition, Vol. 2, SAS Institute Inc., SAS Campus Drive, Cary, NC 27513.
- Spitters, C.J.T., 1986. Separating the diffuse and direct component of global radiation and its implications for modelling canopy photosynthesis. Part II. Calculation of canopy photosynthesis. Agric. For. Meteorol. 38, 231-242.