

THE IMPLICATIONS OF TERROIR FOR DEVELOPMENT OF BOTRYTIS CINEREA INTO GREY ROT OR NOBLE ROT ON GRAPES OF VITIS VINIFERA L. CV. CHENIN BLANC

Carey V.¹, Barbeau G.², Cadot Y.², Conradie W.J.³ & Vermeulen A.³

¹Department of Viticulture and Oenology, Stellenbosch University, Private Bag X1, 7602 Matieland, South Africa; Tel.: +27 21 808 4784; Fax: +27 21 808 4781; e-mail: vac@sun.ac.za

²INRA-UVV, 42, rue Georges Morel, 49071 Beaucouzé Cedex, France

²Tel.: +33 2 41 22 56 72; Fax: +33 2 41 22 56 65; e-mail: gerard.barbeau@angers.inra.fr, yves.cadot@angers.inra.fr

³ARC Infruitec-Nietvoorbij, Private Bag X5026, 7599 Stellenbosch, South Africa

³Tel.: +27 21 809 3100; Fax: +27 21 809 3002; e-mail: kobusc@infruit.agric.za, abraham@infruit.agric.za

Summary

The cultivar Chenin blanc originated in the Loire valley and is cultivated extensively in South Africa. It is a multifaceted cultivar that can be used to produce many wine styles, depending on the climatic conditions of the region and the terroir. It is sensitive to infection by *Botrytis cinerea*, responsible for grey rot and, under specific conditions, noble rot of berries. The latter is desired for the production of dessert style wines, while grey rot, and resulting secondary infections, result in loss of income.

Networks of experimental plots to monitor time of infection by *Botrytis cinerea* and further development of this fungus on Chenin blanc under different soil-climate conditions were established in the Coteaux du Layon A.O.C. (France) and in the Paarl area (South Africa). Edaphic conditions, microclimate, canopy development and berry ripening were monitored. The degree of infection by *Botrytis* and development of natural desiccation was assessed visually using a percentage classification system.

The plots induced different responses with respect to timing of key phenological events and the growth vigour of the grapevines. Under both French and South African conditions it appeared that soils on parent rock in early stages of weathering (and warmer climatic conditions in South Africa) resulted in an earlier phenological cycle, a smaller canopy with little regrowth, earlier ripening and lower malic acid contents in the berries. These plots were also characterised by higher levels of noble rot and/or natural desiccation depending on the climatic conditions of the region and/or season. Plots having deeper soils on clay (and cooler climatic conditions in South Africa) resulted in a longer growth season, larger canopies, higher malic acid content in the berries and generally higher levels of grey and/or secondary rot.

This information is of significance for site selection of Chenin blanc, as optimal terroir choice will result in reduced necessity for chemical control of *Botrytis cinerea* and a better adequacy to the desired type of wine.

Keywords : *Vitis vinifera*, Chenin blanc, terroir, *Botrytis cinerea*, natural desiccation

Rôle du terroir sur l'évolution de *Botrytis cinerea* vers la pourriture noble ou la pourriture grise des baies de Chenin (*Vitis vinifera* L.)

Le Chenin, originaire de la vallée de la Loire est très cultivé en Afrique du Sud. C'est un cépage polyvalent capable de produire des types de vins très différents selon les conditions climatiques et le terroir. Il est sensible à *Botrytis cinerea*, agent responsable de la pourriture grise, et sous certaines

conditions de la pourriture noble. Cette dernière est recherchée dans le cadre de l'obtention de vins blancs liquoreux. Au contraire, la pourriture grise et les infections secondaires qui en dérivent déprécient la vendange.

L'apparition et le développement du *Botrytis* sur le Chenin ont été étudiés au travers de réseaux de parcelles expérimentales établies sur différents milieux physiques, à la fois dans l'A.O.C. Coteaux du Layon (France) et dans la région de Paarl (Afrique du sud). Le suivi a concerné les conditions édaphiques, le microclimat, le développement végétatif et la maturation des baies. Le pourcentage d'infection des baies par le champignon ainsi que le passerillage ont été notés selon une échelle visuelle.

Les conditions physiques du milieu naturel induisent une réponse différentielle de la vigne en termes de dates des stades phénologiques et vigueur de la plante. Que ce soit en France ou en Afrique du sud (alors que les conditions climatiques sont plus chaudes en Afrique du sud), les sols développés sur une roche mère peu évoluée induisent une plus grande précocité du cycle, un développement végétatif plus réduit avec un faible développement des entre cœurs, une maturation des baies plus précoce avec une teneur plus faible en acide malique. Ces parcelles sont aussi caractérisées par des niveaux plus élevés de pourriture noble et/ou de passerillage selon les conditions climatiques de la région et/ou de la saison. Les parcelles où le sol est plus profond et plus argilisé (mais aussi pour l'Afrique du sud, où les conditions climatiques sont plus fraîches) induisent un allongement du cycle de la vigne, un plus grand développement de l'appareil végétatif, des plus fortes teneurs en acide malique et généralement un développement plus important de la pourriture grise et d'autres pourritures secondaires.

Ces résultats présentent un intérêt certain pour le choix du site d'implantation du cépage Chenin ; en effet une adéquation optimale du cépage avec le terroir impliquera une moindre nécessité de contrôler chimiquement le *Botrytis* et permettra l'élaboration du type de vin souhaité.

Implicaciones del terroir en relación con el desarrollo de *Botrytis cinerea* en bayas de Chenin (*Vitis vinifera* L.) y su evolución hacia la podredumbre gris o la podredumbre noble.

El Chenin, originario del valle del río Loire en Francia, es muy cultivado en Africa del sur. Es una variedad polyvalente capaz de producir diferentes tipos de vino, dependiendo de las condiciones climáticas de la región y del terroir. Es sensible a la infección por *Botrytis cinerea*, hongo responsable de la podredumbre gris, y, en condiciones particulares, de la podredumbre noble. Está deseada para la obtención de vinos licorosos, cuando la podredumbre gris y las infecciones secundarias que la acompañan resultan en pérdida de ingresos.

El momento de la aparición del *Botrytis* y su desarrollo en la variedad Chenin han sido investigados por medio de redes de parcelas experimentales, tanto en el área (A.O.C.) de los Coteaux du Layon en Francia, como en el área de Paarl en Africa del sur. El seguimiento fue enfocado hacia las condiciones de suelo, el micro clima, el desarrollo vegetativo y la maduración de las uvas. El porcentaje de infección por el hongo y la desecación natural de las uvas fueron notadas de acuerdo a una escala visual.

Las parcelas inducen respuestas diferentes de la vid en cuanto a fechas de los estados fenológicos y vigor de las plantas. Tanto en Francia como en Africa del sur (bajo un clima mas caliente), los suelos desarrollados sobre una roca-madre poco evolucionada resultaron en una mayor precocidad del ciclo de la vid, una vegetación más reducida con poco rebrotes, una maduración avanzada de las bayas y un más bajo contenido en ácido málico. Estas parcelas se caracterizaron tambien por niveles más altos de podredumbre noble y/o natural desecación, de acuerdo a las condiciones climáticas y/o la estación. Las parcelas con suelo más profundo y arcilloso (que también corresponden a condiciones climáticas más frías en Africa del sur) indujeron un alargamiento del ciclo, un mayor desarrollo

vegetativo, un contenido más alto de las bayas en ácido málico así como niveles más altos de podredumbre gris y/o podredumbres secundarias.

Estos resultados presentan un gran interés en cuanto al escogimiento del sitio de plantación del Chenin, pues su óptima adecuación al terroir resultará en una menor necesidad de control químico del *Botrytis* y permitirá la elaboración del tipo de vino deseado.

Introduction

Chenin blanc is a multi-faceted cultivar that originated in the Loire Valley (Galet, 1979) where it is used to produce dry and sweet wines. In South Africa it is one of the cornerstones of the industry and it is used in the production of sparkling, dry, sweet and sherry type wines as well as being distilled to produce brandy and spirits (Orffer, 1979). In order to produce sweet wines, the sugar within the berries must be concentrated. This can occur either as a result of natural desiccation of the berries or due to infection by *Botrytis cinerea*. Inoculation by *Botrytis cinerea* generally occurs during the spring (from bloom to bunch closure) on the rachis (du Preez, 2002). Such symptomless infections, established early in the season, give rise to symptom expression under wet conditions later in the season, generally from the inner bunch (Du Preez, 2002, Holz, 2001), after the fungus has been given a "helping hand" by means of viticultural practices, cultivar characteristics and environmental factors (Holz, 2001). In most cases, infection of grape berries by *Botrytis cinerea* results in grey rot, with subsequent reduction in quality, but under certain growth conditions it may lead to noble rot (Donèche, 1993). The prerequisite for development of noble rot is that the berries should reach maturity intact (Pucheu-Planté & Seguin, 1978) and that there are alternating short damp periods and longer dry periods (Donèche, 1993). In this case symptom expression occurs rapidly ca. 15-20 days before maturity (Donèche, 1993). Chenin blanc is particularly susceptible to infection by *Botrytis cinerea* due to its compact bunches and vigorous growth habit (Orffer, 1979) but this infection often transforms to common rot or "sour rot". Sour rot is the result of infection by yeasts and acetic bacteria through skin fissures caused by *B. cinerea* or berry cracking (Donèche, 1993). Differences in a cultivar's reaction to *B. cinerea* between site and season and the relation to wine quality and character are obviously linked to climatic conditions, but the soil effect on determining the type of mould is also recognised, although not clearly understood (Ribereau-Gayon, Ribereau-Gayon & Seguin, 1980). The development of *B. cinerea* infection into noble or grey rot appears to be affected by many factors and Donèche suggested in 1993 that it appears worthwhile to conduct "ecologic research on soils likely to produce noble rot naturally". This paper describes such a study in South Africa and France.

Materials and methods

Experimental plots were selected in commercial vineyards of *Vitis vinifera* L. cv. Chenin blanc in the Paarl, South Africa, wine producing region (Table 1). These results were compared to a similar network of plots established in the Coteaux du Layon, France, (Table 2) for which results have already been published (Barbeau *et al.*, 2001).

Table 1. Experimental plots of Chenin blanc in Paarl, South Africa.

	Soil	Aspect	Altitude	Rootstock	Irrigation
AS	Deep red soil (>100 cm) with restriction to root growth at 80 cm due to soil compaction	W	285 m	Richter 99	Micro-sprayers
MB	Deep yellow soil (>90 cm)	E	405 m	Richter 99	None
MO	Medium deep soil (55 cm) on a bed of clay	ENE	305 m	Richter 99	Hop-a-long
DV	Medium deep gravel-clay soil (70 cm) on weathered Malmesbury shale.	WNW	119 m	Richter 99	Micro-sprayers

Table 2. Experimental plots of Chenin blanc in the Coteaux du Layon, France.

	Soil characteristics and properties	Terrain model
VAL	Shallow soil (<50 m) on Precambrian schists. Early spring warming. Low water reserve.	Rock type
BLO	Deep soil (>80 m on clay and altered Ordovician-Devonian spilite. Slow spring warming. High water reserve.	Weathered type

Twenty-four vines (8 randomised sets of 3 vines) per experimental plot were monitored for phenological dates; primary leaf area from budburst to beyond flowering and total soluble solids, total titratable acidity, pH, tartaric and malic acids and berry mass from bunch closure to ripeness. Symptoms of *Botrytis cinerea* and natural desiccation were monitored on thirty-two bunches per plot on a weekly basis during the last part of the season. The percentage infection per category (Fig. 1) was divided into five classes and each bunch was scored appropriately. The mean value per evaluation was recalculated as a percentage using the mid-point of each class. At maturity, bunches on the 24 vines were harvested for microvinification according to standard winemaking procedures. The remaining grapes were selected at appropriate stages for the production of natural sweet and noble late harvest wine styles. These wines were sensorially analysed by trained panels. Micro-climate was monitored by sensors in the bunch-zone.

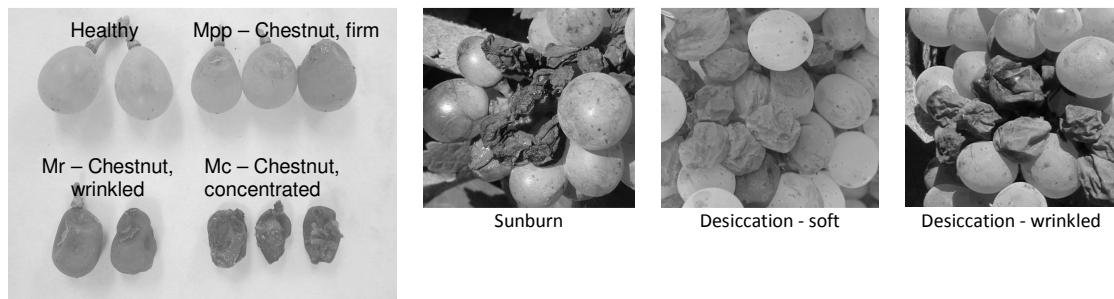


Figure 1. Classification scheme for symptoms of *Botrytis cinerea* and natural desiccation of grape berries.

Microclimatic data (daily mean, maximum and minimum temperatures; daily mean, maximum and minimum relative humidity, hourly relative humidity and number of hours with a relative humidity greater than 90%) were compared through Student t-tests.

Analyses of Variance (ANOVA - GLM procedure) were performed on each variable (vicultural and oenological performance and development of *Botrytis cinerea* and secondary infections or natural desiccation in Paarl, South Africa) using SAS 8.1 to test for significant “Year” and “Plot” effects. Relationships between vicultural parameters, berry composition and development of *Botrytis cinerea* and natural desiccation at harvest of the 24 vines, 14 days after harvest and 30 days after harvest in Paarl were analysed through principal component analysis for each season individually using Statistica 6 software. Results from the sensory analyses of the South African wines were also analysed by means of principal component analyses with Statistica 6.

Results and discussion

Seasonal climate: The four seasons included in the investigation differed with respect to their climate. During the 1999/2000 season a warm October was followed by a heat wave in December and January. The conditions were dry with little rainfall and low relative humidity values. The 2000/2001 season also had warm conditions in October and November but December and January were cooler than the 4 year average. February was again hot. Conditions were once again very dry. During 2001/2002, November was slightly warmer than average but relatively humid following a damp October. January was cooler than average, with a relatively high rainfall, and was followed by a moderate February. The 2002/2003 season was characterised by very cool conditions in October and November, moderate temperatures during December and January and again very cool conditions in February and March. This season was also characterised by a higher than average rainfall and high relative humidity values during February and March.

Microclimate: The microclimate of the plots in Paarl differed with MB and MO being significantly cooler than AS and DV. Despite statistically significant differences in relative humidity values for these plots, it was less easy to establish a general rule for relative humidity as there were differences between seasons (Fig. 2). MB generally had higher values early in November. This coincides with the flowering period and would thus be conducive to infection of the permanent structural parts of the bunch. In the Côteaux du Layon, for the period 1996-2000, the only microclimatic data to show consistent statistical significance was daily maximum relative humidity where BLO had higher values (Barbeau *et al.*, 2001). Microclimate would, therefore, appear to play a minimal role in site differences in infection by and development of *Botrytis cinerea* in this region.

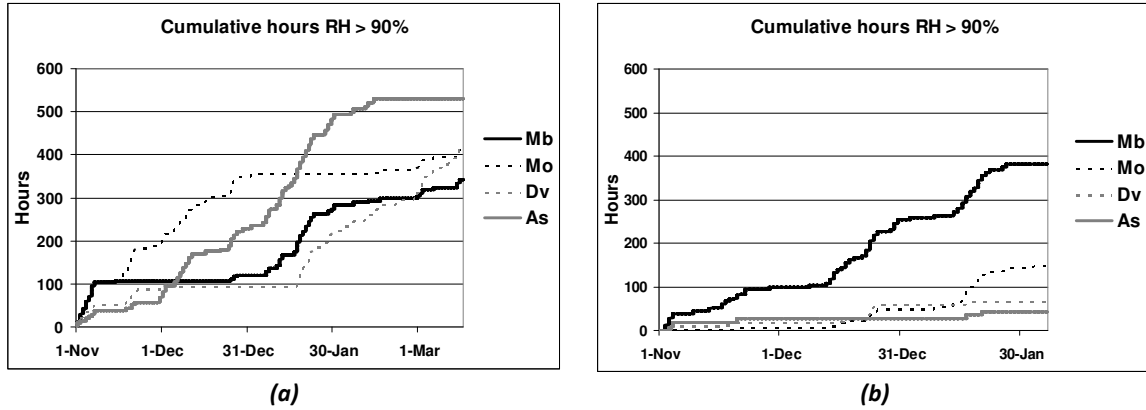


Figure 2. Cumulative hours with relative humidity values greater than 90% calculated from 1 November in (a) 2001/2002 and (b) 2002/2003 in the bunch zone of experimental plots in the Paarl wine producing area, South Africa.

Soil conditions: In South Africa DV is the only plot that approaches the rock variant of the terrain model described by Morlat (1997). Despite the advanced weathering of the soil at AS, it may mimic the reactions of the intermediate variant due to sub-soil compaction that limits root growth at 80 cm. MB and MO can both be classified as the weathered variant.

Performance of the grapevine and berry composition: DV in South Africa had significantly the earliest date of harvest at normal maturity despite no significant differences in dates of budburst or flowering. This plot also had the fastest canopy development, having the highest primary leaf area at flowering ($p \leq 0.1$). The faster shoot development at DV lead to earlier topping interventions, but little regrowth recurred due to the poor buffer capacity provided by the root system. This, together with the trellising system, resulted in a more open canopy, which was the probable cause of a significantly lower must titratable acidity ($p \leq 0.05$). DV was also the plot with the highest yield ($p \leq 0.05$). The 24-vines at DV were harvested at a significantly higher maturity index, followed by AS and lastly by MO and MB, which did not differ significantly from each other.

Although malic acid contents at ripeness did not differ significantly between plots, DV had the lowest and MB and MO the highest mean levels, which were reflected in the seasonal dynamics. For example, despite DV having the highest levels of malic acid at the time of harvest of the 24 vines (normal maturity) during the 2001/2002 season, malic acid started reducing earlier and reached lower final levels than the other plots (Fig. 3).

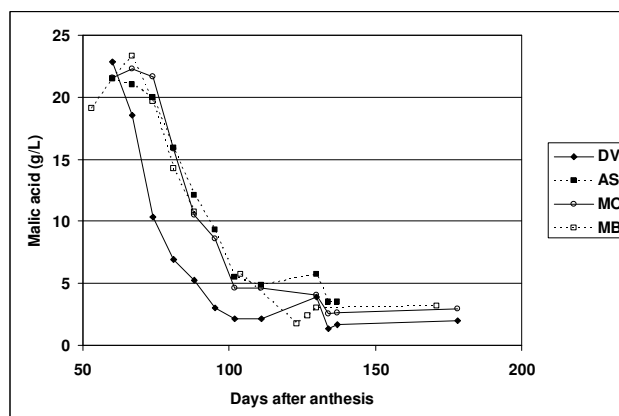


Figure 3. Malic acid content of berry samples taken from the Chenin blanc experimental plots in Paarl, South Africa, during the 2001/2002 season.

Development of symptom expression by Botrytis cinerea and natural desiccation: Levels of *Botrytis cinerea* symptoms were low in all seasons for the experimental plots in Paarl, South Africa, with the highest values (6%) being recorded at DV prior to harvest of the 24 vines in 2002. In the Coteaux du Layon, by comparison, values of ca. 87% symptom expression of the various facies of *Botrytis cinerea* were noted in 2000 at VAL.

The weekly data in South Africa showed that DV was the plot that showed the first symptoms of development of noble rot as well as developing the highest levels each season, although these levels were generally low (<6%). The levels of *Botrytis cinerea* symptom expression in Paarl decreased as the season progressed, while levels of secondary rot (usually sour rot) increased. Levels of secondary rot were high with levels of 50% being recorded at MO on 20 March 2002 (16 days after harvest of 24 vines). These observations suggest that, for the vineyards monitored in the Paarl network, any symptom expression by *Botrytis cinerea* provides a point of entry into the berry for the organisms associated with sour rot. This holds serious economic implications, both in terms of yield loss and extra labour costs, as grapes infected with sour rot cannot be used for wine production.

Using principal component analyses, DV could be distinguished from the other plots along factor 1 for the 2000/2001, 2001/2002 and 2002/2003 seasons, while in 1999/2000 DV and AS were separated from MO and MB along factor 1. DV was generally associated with earlier canopy development, a higher maturity index (due to lower titratable acidity values at harvest) and higher levels of natural desiccation. DV is the only plot in the Paarl network that could be considered as belonging to the rock variant as described by Morlat (1997). In the Loire Valley it has been found that this rock variant favours an earlier growth cycle, a lower risk of the development of grey or secondary rot and increased potential for the development of natural desiccation (Barbeau et al., 2001).

In the 1999/2000 season, AS developed sour rot early in the season and had the highest levels at harvest of the 14 vines. This development appeared to be associated with a rapid increase in berry size and larger berries (Fig. 4a), which may have resulted in berry fissures and probably resulted in more compact bunches. Compact bunches provide an environment conducive to symptom expression by *Botrytis cinerea*, and subsequent secondary infections, due to capture of moisture and berry cracking as a result of pressure. During this same season, the levels of sour rot increased dramatically at DV 140 days after anthesis, ca. 1 month after normal maturity (Fig. 4b). At this time there was ca. 50% natural desiccation, which meant that a natural sweet wine could be made from healthy grapes, while at AS these levels were lower (ca. 38%) .

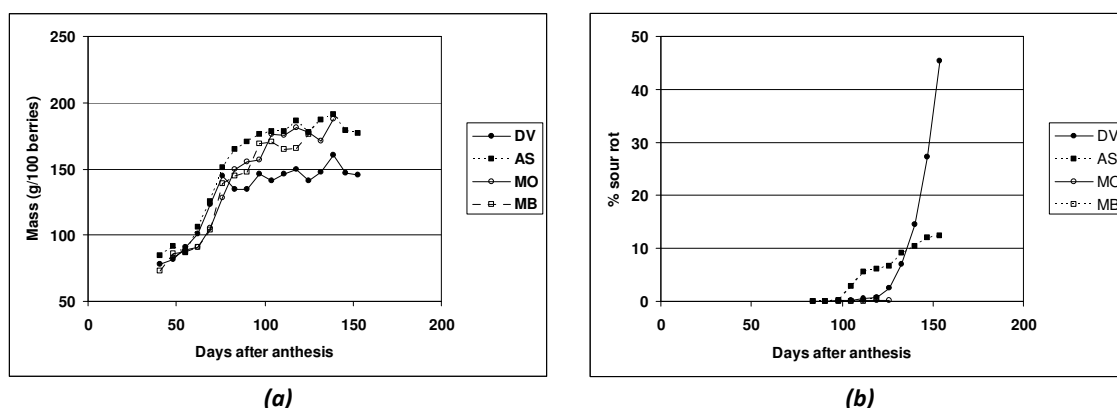


Figure 4. (a) Berry size (g/100 berries) and (b) percentage sour rot infection as measured for the Chenin blanc experimental plots in Paarl, South Africa, during the 1999/2000 season.

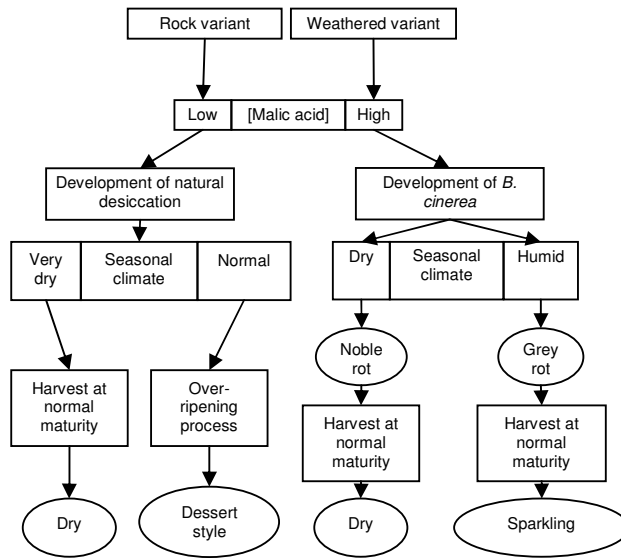
Wine quality and character: Statistical analyses of the wines from the 2000/2001 season showed that for the Chenin blanc wines harvested at maturity, DV resulted in wines that were significantly fuller in body than the other wines as well as having a more significantly more intense citrus aroma than AS. In the 2001/2002 season, the only sensory characteristic to differ significantly was that of tropical fruit aroma where MO had a significantly more intense tropical fruit aroma and higher quality. In the 2002/2003 season, Ashanti had a poor colour and more intense “other” aroma characteristics, despite having a fuller body. This was probably due to a higher percentage of secondary infections (mostly sour rot) at harvest compared to the other plots.

Principal component analyses of sensorial data from each year (data not shown) indicated that in the 2000/2001 (dry, cool ripening period), the plots that were harvested later (second selections from MO and MB and third selection from AS) were associated with a higher quality natural sweet wine with a better balance, and typical aroma characteristics. Due to the high degree of natural desiccation, all grapes were harvested at DV at the first selection. In the 2001/2002 season (wet, cool conditions in January, moderate February), the first selections from MB, MO and the two selections from DV resulted in wines of higher quality. An ANOVA analysis showed that AS (one selection only) was of a significantly lower quality. In the 2002/2003 (cool, damp ripening conditions), the third selection from MB and both selections from AS and DV were associated with a higher quality score.

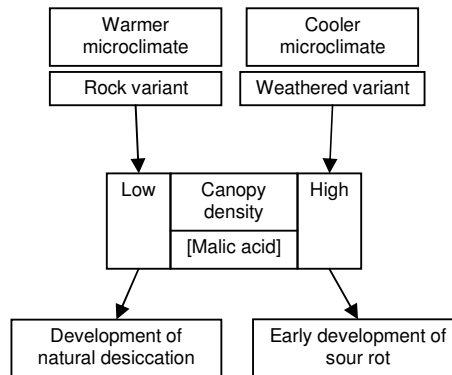
Conclusions

During the project duration (1999 to 2003) climatic conditions during the growth season in the Paarl wine producing district were not conducive to high percentages of infection by or symptom development of *Botrytis cinerea*. It was nonetheless possible to prepare natural sweet wines from selected grapes that were predominantly desiccated but where there was also some development of noble rot. It is clear that the seasonal climate has the strongest effect on the degree of symptom expression of infections by *B. cinerea* and development of secondary or sour rot. The season in which *B. cinerea* symptoms developed to the greatest extent was 2001/2002 where higher levels of both noble and grey rot were recorded. This, however, also led to very high levels of secondary infection (sour rot) requiring careful selection of grapes for production of quality wines. The higher levels of infection by *B. cinerea* may have been due to the rainy conditions around bloom and infection of the permanent bunch structural parts. Rain in January was associated with symptom expression and development of grey and noble rot. Despite the large seasonal differences the site effect cannot be ignored. DV could generally be separated from MO and MB with respect to phenological cycle, vegetative growth, berry composition and development of noble rot or natural desiccation. AS was generally closer in reaction to MO and MB, but the difference was not as clear cut. In the 2001/2002 season, with the highest symptom expression as well as the highest levels of secondary infections, DV was associated with the lowest percentages sour rot and it was possible to make two selections of grapes for the production of natural sweet wine without a loss of quality that was associated with the other plots due to development of sour rot. The more open canopy and resulting drier bunch microclimate associated with the shallower soil at this plot was conducive to the development of natural desiccation and was less sensitive to development of sour rot. DV also had the fastest reduction in malic acid content during this season. During this same season MO recorded the highest levels of grey rot and secondary rot (sour rot). MO has a highly weathered soil with a high clay content. Although point quadrat measurements were not performed during this season, MO had the densest canopy and highest percentage of shaded bunches during the two previous seasons, which would have been exacerbated by rainfall in January. Free water may have been captured in the bunches.

At the OIV World Vine and Wine conference in 2001, Barbeau et al. proposed the following conceptual model for development of natural desiccation and *B. cinerea* for Chenin blanc in the Coteaux du Layon:



The results from Paarl, although on a more limited scale due to the lower pressure of *B. cinerea* symptom expression, are not dissimilar from those obtained in the Coteaux du Layon and the following conceptual model can be proposed for a humid season with a higher *B. cinerea* pressure:



The symptom expression of *B. cinerea* and development into either noble rot or grey rot is masked by the secondary infections resulting in sour rot and thus a reduction in wine quality. In a warm, dry year it is possible to retard harvest for the production of natural sweet wines while during a cooler, more humid season it is necessary to harvest earlier in order to retain quality. The risk associated with the production of natural sweet wines is reduced for the rock variant no matter the season. These results emphasize the role that soil (and possibly microclimatic) characteristics, together with the climate of the season, play in the concentration of grape berries for the production of dessert style wines.

Bibliography

Barbeau, G., Cadot, Y., Stevez, L., Bouvet, M. H., Cosneau, M., Asselin, C. & Mège, A., 2001. Role of soil physical properties, climate and harvest period on must composition, wine type and flavour (*Vitis vinifera* L., cv. Chenin). In: Proc. 26th O.I.V. World Vine & Wine Congress, October 2001, Adelaide, Australia.

Donèche, B. J., 1993. Botrytized wines. In Fleet, G. H. (Ed.). Wine microbiology and biotechnology. Taylor and Francis, London. 327-348.

- Du Preez, I. F., 2002. Infection pathways of *Botrytis cinerea* on selected wine grape cultivars. MscAgric thesis, Stellenbosch University, South Africa.
- Galet, P., 1979. A practical ampelography. Translated and adapted by L. T. Morton. Cornell University Press, Ithaca and London.
- Holz, G., 2001. The occurrence and control of *Botrytis cinerea* (grey mould) of grapes: A South African perspective. <http://www.wynboer.co.za/recentarticle/0901botrytis.php3>.
- Morlat, R., 1997. Les Facteur naturels des terroirs viticoles. Méthodologie de leur caractérisation. In: Proc. 22nd O.I.V. World Vine & Wine Congress, Buenos Aires, Argentina.
- Orffer, C. J., 1979. Wine Grape Cultivars in South Africa. Human and Rousseau, Cape Town and Pretoria.
- Pucheu-Planté & Seguin, 1978. Pourriture vulgaire et pourriture noble en Bordelais. *Connaiss. Vigne Vin* 12, 21-34.
- Ribéreau-Gayon, J., Ribéreau-Gayon, P. & Seguin, G., 1980. *Botrytis cinerea* in Enology. In Coley-Smith, J.R., Verhoeff, K. & Jarvis, W.R. (Eds). *The Biology of Botrytis*. Academic press, New York.