underlying physiological processes of the developmental stage. The base temperature of 0ºC has the advantage for model users in that it is more simple to calculate during the growing season when minimum temperatures are less likely to drop below 0ºC. Therefore, in such cases its application represents a simple addition of accumulated daily average temperatures (from the 60th day of the year).

5 CONCLUSIONS

We have shown that general process-based models can be successfully applied to and validated for the grapevine. A simple model, GFV corresponding to SW (t_0 at 60 days, *Tb* value of 0°C) has been selected, optimised and shown to be efficient to predict flowering and veraison at the species and varietal level. The model was validated and showed greater predictive power compared to existing models. Its simplicity makes it easy to use, and enables further adoption of the model to predict the varietal timing of flowering and veraison under a changing climate.

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Vine nitrogen status and the terroir effect: a study on cv. Doral in the Vaud vineyard (Switzerland)

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ABSTRACT

A 3-year study was conducted in the Vaud vineyard (Switzerland) to evaluate the effects of « terroir » on the ecophysiology and fruit compostion of *Vitis vinifera* L. cv. Doral and the characteristics of the wine made therefrom. The impact of soil on the vine-fruit-wine continuum was evaluated at 13 locations in the Vaud during the 2007-2009 seasons. Except for soil, the vineyards presented almost identical climatic characteristics and used similar cultivation techniques. The aim of this chapter was to assess whether soil might be a major environmental factor explaining the terroir effect through its effect on vine nitrogen status. We monitored the nitrogen status of the vines by measuring yeast assimilable nitrogen (YAN) in the must. The soil modulated vine nitrogen status by its fertility and rooting depth. Low vine nitrogen status induced a highly-soluble solids content, low malic acid content and high pH in fruits, resulting in small berries and low vine vigour. Wines were produced in a standardised manner from each location; then, they were subjected to sensory and chemical evaluation. YAN in musts was the parameter that best explained the variation in sensory characteristics of the wine made from grapes from the different locations. Wines made from grapes with low YAN values had negative sensory characteristics such as astringency and low aroma complexity scores. Therefore, vine nitrogen status was a key parameter contributing to the terroir effect. Furthermore, this work provides evidence of how geopedology can influence vine nitrogen status, fruit composition and sensory attributes of wines.

Keywords: soil categories, rooting depth, leaf and must nitrogen status, wine characteristics.

1 INTRODUCTION

In addition to climate, soil makes a major contribution to the terroir effect. However, the role of soil has not been studied widely and is still debated. For example, neither Noble [1] nor Bader and Wahl [2] found any relationship between soil and wine, whereas others authors have observed that soil affects both grape and wine composition. Most of the studies on this subject have described the effects of soil, but few have identified the contributing factors. The soil water holding capacity and its influence on vine water status may contribute to soil's effect [3,4]. However, except

for soil water availability, little evidence is available showing that other factors contribute to the effect of soil on wine. Wine characteristics have been reported to depend on soil fertility [5], soil texture [6], and soil depth [7].

In the present study, the modulation of vine nitrogen status by soil and its influence on fruit and wine characteristics were examined. Nitrogen is a mineral element that is required in large amounts by vines. Therefore, nitrogen is one of the most influential mineral nutrients in the physiology of the grapevine [8]. Factors influencing vine nitrogen status can be divided into three groups: genetic factors, cultivation practices, and environmental factors. Genetic factors include cultivars and rootstocks, and cultivation practices include the time, form and rate of fertilisation, and soil management [9]. However, little research has been reported on the dependence of vine mineral uptake on environmental conditions, particularly soil parameters.

Therefore, we conducted this study to analyse the relationship between wine attributes and soil properties. We used vineyards presenting almost identical climatic and topographic characteristics. The same viticultural cultivation techniques and winemaking protocols were followed. Because the vineyards were situated on different soils, we assumed that any differences between the wines could be attributed to the soil. The objective was to determine whether vine nitrogen status is a key environmental factor contributing to the variable attributes of wine produced from different soils.

2 MATERIALS AND METHODS

2.1 Vineyard sites

The study was conducted on 13 locations in La Côte region of Vaud vineyards (Switzerland). The climatic features of this region include a mean July temperature of 18.6 °C, an annual average rainfall of 945 mm and a growing season rainfall of 583 mm. The locations were planted with *Vitis vinifera* L. cv. Doral (Chasselas x Chardonnay). The locations were planted in 2003 and grafted on 3309 C rootstock. Vines were trained in espalier (single Guyot with vertical shoot positioned foliage). The planting density was 6400±700 vines/ha.

2.2 Soil category and cultural practices

The different soils were identified according Letessier and Fermond (2004) and then regrouped in two categories for this work: one group of the bottom moraines, highly compact soils (eight locations), and a second group consisting of colluvia (two locations) and gravelly moraines (three locations).

Yield was limited by cluster thinning at the stage of pea-sized berries. The leaf area/fruit weight ratio was over 1 m^2/kg. Agronomical practices (fertilisation and floor management) were recorded for each location. The locations on bottom moraines had an average N fertilisation rate per ha and year of 25 kg N and the other 15 kg N. In the majority of locations, floor management was permanent sod with grass in all inter-row and herbicide-treated strips under the vines.

Foliar analysis was performed to determine the levels of leaf nitrogen (Kjeldahl method) and phosphorous (Sol-Conseil, Changins (CH)). The samples consisted of 30 leaves taken in the cluster region and gathered at veraison. Leaves (with petioles) were washed, oven-dried, grounded and analysed. Yeast assimilable nitrogen (YAN) was estimated by NIR spectroscopy (WineScan®, FOSS NIRSystems, USA). The YAN assessment is based on the Formol titration of Sörensen (Aerny, 1996). 150 kg of grapes were manually harvested and used for wine making. Microvinification was then conducted identically for all lots by the same winemaker. Sensory analysis of the experimental wines was conducted on two replicates after two month from bottling.

2.3 Leaf, fruit and wine analyses

Foliar analysis was performed to determine the levels of leaf nitrogen (Kjeldahl method) and phosphorous (Sol-Conseil, Changins (CH)). The samples consisted of 30 leaves taken in the cluster region and gathered at veraison. Leaves (with petioles) were washed, oven-dried, grounded and analysed. Yeast assimilable nitrogen (YAN) was estimated by NIR spectroscopy (WineScan®, FOSS NIRSystems, USA). The YAN assessment is based on the Formol titration of Sörensen (Aerny, 1996). 150 kg of grapes were manually harvested and used for wine making. Microvinification was then conducted identically for all lots by the same winemaker. Sensory analysis of the experimental wines was conducted on two replicates after two month from bottling.

2.4 Statistical analyses

Statistical analysis was carried out with R software (R Development Core Team, Vienna, Austria). Duncan's test was used for mean differentiation. The significance of the regression is indicated with asterisks: *, **, *** indicates significance at $p < 0.05$, 0.01, and 0.001. The grape composition data were analysed with a two-way ANOVA procedure. Sensory data were examined with Principal Component Analysis (PCA) using a correlation matrix to determine whether the soil categories could be separated from each other.

3 RESULTS

Leaf nitrogen content at veraison was significantly lower for vines established on bottom moraines for all three seasons. Leaf nitrogen content was significantly lower in 2007 than in the other years for both soil categories. The YAN level in berries was dependent on soil category (Fig. 1). Vines growing on bottom moraines showed significantly lower nitrogen content in musts for all three vintages (-20 to -30%). Differences between the two soil categories were noticeable from veraison to harvest.

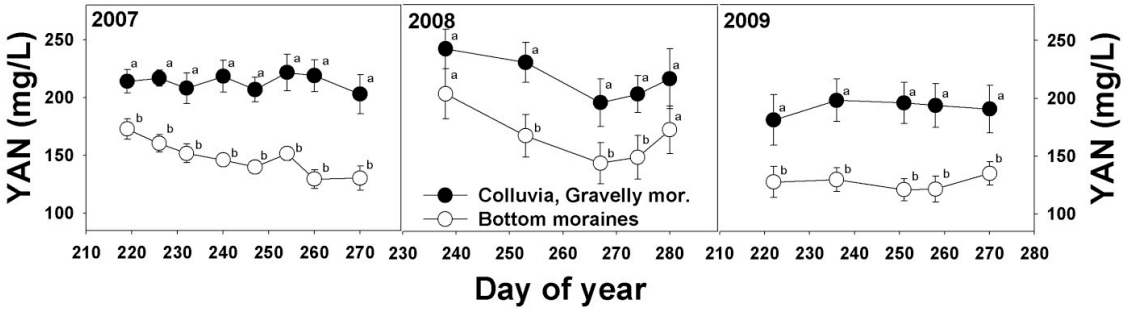

Figure 1. Seasonal evolution of YAN (yeast assimilable nitrogen) in grapes for each soil category. Doral, 2007-2009.

A significant positive relationship existed between YAN and the malic acid content in grapes at harvest over the three years. YAN was positively correlated with berry weight (significant (***) only in 2007). Soluble solids content (SSC) tended to be negatively correlated with YAN (significant (*) only in 2008). Except for 2009, YAN was correlated with must pH. Soil category had a significant effect on the average level of all fruit parameters, except for titrable acidity (TA) and tartaric acid content. Between years (vintage effect), we observed a significant difference between the means of most fruit parameters, except for YAN and berry weight. On average, the vines on bottom moraines showed smaller values of YAN (-40 %), malic acid (-15 %), and pH (-1 %) but higher soluble solids content (+3 %). For the majority of fruit parameters, the vintage effect was the dominant factor, and soil category accounted for only a tiny fraction of the observed variation. In contrast, YAN was the parameter most affected by soil category, and vintage effect exhibited no significant effect on it.

The results of the sensory analysis are depicted in Figure 2. Comparisons about sensory data were made within a year, not between years. In 2007, YAN was positively correlated with the olfactory complexity score (R^2=0.36*). Moreover, YAN was also positively related to the colour intensity score (R^2=0.35*) and the overall quality score (R^2=0.43*). The negative correlation between YAN and the astringency score was particularly strong (R^2=0.82***). In 2008, YAN was correlated with the perceived acidity (R^2=0.43*), astringency, and persistence scores. Although the relationship was not significant, the overall quality score was positively related to YAN. For 2009, significant correlations were observed between YAN and the wine sensory descriptors olfactory complexity, overall quality, and persistence. The wines made from grapes grown on the two soil categories exhibited significant differences in the sensory analysis for all three years. The wines produced on bottom moraines were mainly characterised by a high astringency score, low olfactory complexity, and a low overall quality score.

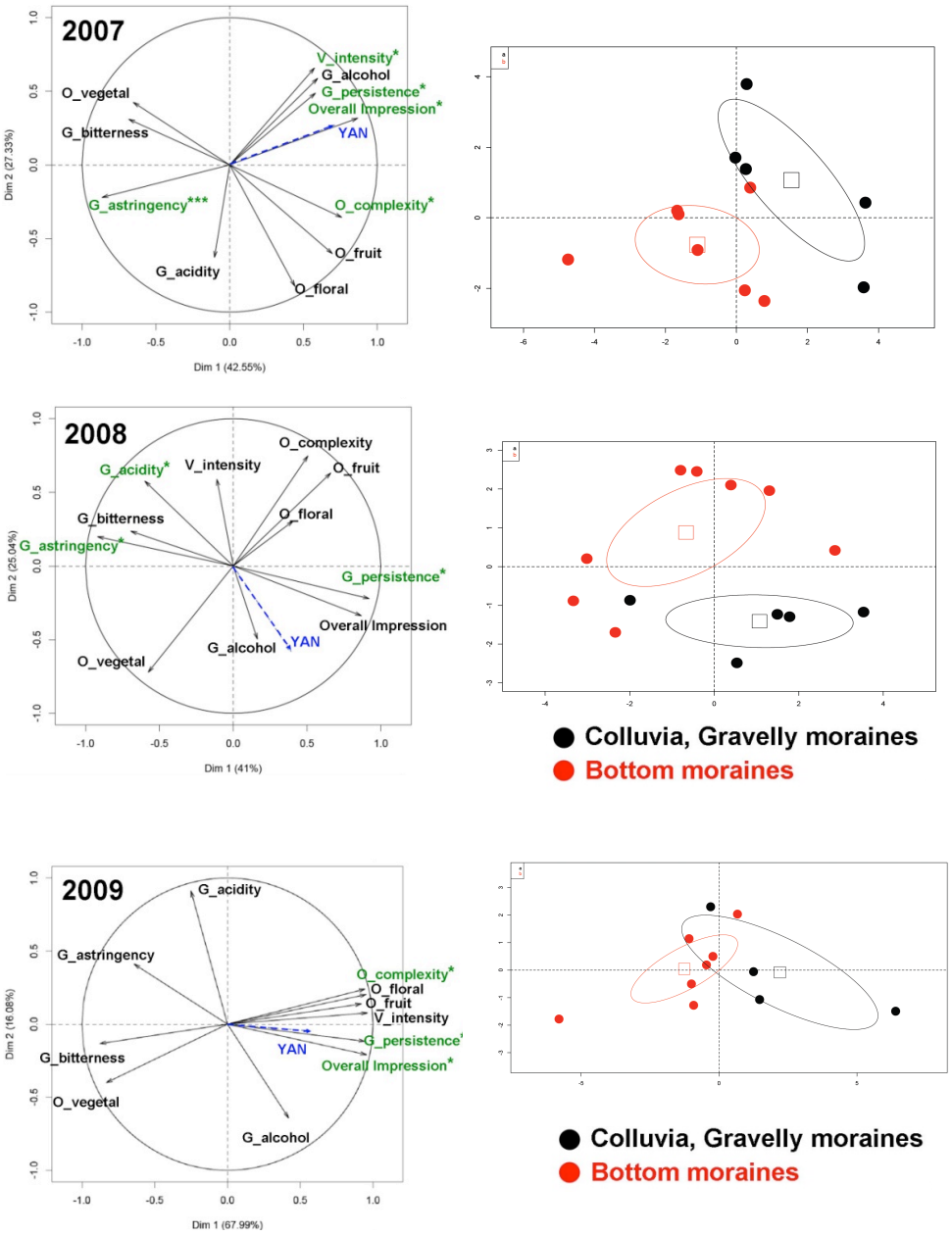

Figure 2. PCA representation of the sensory variables. Barycentre of each soil category are represented with their confidence interval at 95%. Doral, 2007-2009.

4 CONCLUSIONS

Soil, through its fertility and vine rooting depth, was found to be an important environmental parameter that modulates vine nitrogen level, vine physiology, fruit composition, and the characteristics of the resulting wine. Vine nitrogen status is a key factor contributing to the terroir effect, which usually depends on fertilisation practices. Because we used similar fertilisation practices, soil parameters were primarily responsible for the variations in vine nitrogen status. The characteristic that best explained the variable sensory characteristics of the wines made from grapes from the different sites was the level of yeast assimilable nitrogen in the must.

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Grapevine performances in five areas of 'Chianti Classico'
Comportement de la vigne en cinq zones des « Chianti Classico »

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ABSTRACT
The research was carried out in the 'Chianti Classico' area and it was part of the 'Chianti Classico 2000' research project. The performances 'Sangiovese' grapevine (clone 'SSF-A548') grafted on '1103P' and '420A' rootstocks, were evaluated during a six years period, on five experimental vineyards located in the Province of Florence and Siena. The vineyards were established at a density of 3500 plants per hectare, trained to horizontal spur cordon (m 0.7 from the ground) with 30000 buds per hectare. The main meteorological data were monitored by automatic stations and soil analysis was performed at the beginning of the trials. Vines were planted in a randomized block design with four or five replication according to the vineyard size and uniformity. During six consecutive years on 30 plants from each thesis were carried out the following observations: phenology earliness (budbreak, veraison), bud fertility, bunch weight, and yield and pruning weight per plant, must characteristics of the berries at harvest. Physical and chemical analysis of wines obtained from microvinification (made in 500 L containers), were also performed. The climatic differences resulted among the zones of the 'Chianti Classico' examined, had a significant effect on vine phenology also in relationship with altitude, which together to soil characteristics contributed to affect the agronomic behaviour of the three varieties, the must composition and the wine characteristics. Discriminant analysis allowed distinguishing some sites, whose differences can be ascribed to the territorial influence on the vegetative and productive activity of the grapevine, berry ripening and wine composition. Hierarchical influences due to clone 'SSF-A548' according to the site and year are presented.

Keyword: Vitis vinifera, Sangiovese, yield, wine.
Mots-clés : Vitis vinifera, Sangiovese, production, vin.

1 INTRODUCTION

The behaviour of the grapevine varieties is depending on the environmental conditions of the territory which in a wide Denomination of Origin may have a significantly variability. So as is difficult to have uniformity on vegetative and productive behaviour which can affect wine features. Assuming the existence of the variability of the performances of varieties in the space and during the time it is possible to examine the factors responsible of such variation in order to direct the production process and to carry out productive forecasts for the best destination of grapes. In practice the studies of characterization of the main factors able to influence the productive and qualitative obtained in certain territories, can offer a valid support to the technical choices in viticulture management, while more deep and interdisciplinary studies are necessary in order find out a specific terroir, which is of the result of complex interactions between natural, biological and human factors (1, 2), In Tuscany area today remains not completely explored the peculiarities of some territories, like as an example the, and in particular in the Chianti Classico DOCG area in which studies on wide scale have regarded above all the province of Siena (3, 4). In this paper are summarized several results obtained on 'Sangiovese' during the 'Chianti Classic 2000 " research project, in addition to those previously reported (5, 6).

2 MATERIALS AND METHODS

The research was carried out in the 'Chianti Classico' area and it was part of the 'Chianti Classico 2000' research project. The performances of 'Sangiovese' grapevine (nine clones) grafted on '1103P' and '420A' rootstocks, were evaluated during a six years period, on five experimental vineyards located in the Province of Florence and Siena. The vineyards were established at a density of 3500 plants per hectare, trained to horizontal spur cordon (m 0.7 from the ground) with 30000 buds per hectare. The main meteorological data were monitored by automatic stations and soil analysis was performed at the beginning of the trials. Vines were planted in a randomized block design with four or five replication according to the vineyard size and uniformity. During six consecutive years on 30 plants from each thesis were carried out the following observations: phenology earliness (budbreak, veraison), bud fertility, bunch weight, and yield and pruning weight per plant, must characteristics of the berries at harvest. Physical and chemical analysis of wines obtained from vinification (500 L containers), were also performed (7). Data from 'Sangiovese',