Phénologie et maturité des raisins de Cabernet Sauvignon issus de jeunes vignobles dans l'État de Santa Catarina, Brésil – évaluation des influences de l'altitude du vignoble et de son mésoclimat

Phenology and maturation of Cabernet Sauvignon grapes from young vineyards at Santa Catarina state, Brazil – a survey of vineyard altitude and mesoclimat influences

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Abstract

Cabernet Sauvignon grapes from recently planted vines in Santa Catarina State (Brazil), were sampled during ripening from the 2005 and 2006 vintages. The grapes were from five vineyards at different altitudes (774, 960, 1160, 1350 and 1415 m above sea level). Samples were analyzed for total soluble solids (TSS), titratable acidity (TA), Maturation Indices (TSS/TA and TSS *x* pH^2), pH, total anthocyanins, total polyphenol index (TPI) and berry weight at 10-day intervals from véraison to harvest. Glories parameters were evaluated at maturity. Regression analysis and principal components analysis (PCA) were used to relate harvest data (berry composition at maturity and phenological events: budbreak, floraison and véraison) as a function of mesoclimate and vineyard altitude.
For the vintages studied, titratable acidities ranged from 0.59 to 0.955 g/100 mL of tartaric acid and pH from 3.42 to 3.85. In every instance titratable acidities were lower in 2005 than in 2006. At the commencement of ripening the titratable acidity was always much greater at the two highest vineyards. TSS values at harvest were 21.35-23 and 20.77-24.17 for the 2005 and 2006 vintages, respectively. At maturity, total anthocyanins ranged from 310 to 401 in 2005 and from 304 to 477 (mg of malvidin-3-glicoside) in 2006 vintage. TPI levels (mgGAE/100 g of grapes skins) ranged from 652 to 906 in 2005 and from 739 to 966 in 2006 vintage. PCA clearly separated the different sites in relation to berry composition at maturity. Climate was strongly correlated with indices of phenological precocity and with vineyard altitude. A positive relationship was observed between the altitude - air temperature climate parameters and the duration of the grapevine phenological cycle (IPCY). Thus the vineyard at 774 m had the shortest IPCY while the vineyard at 1415 m had the longest IPCY. Other important relationships were observed during maturation of berry grapes: increases in pH and polyphenols and anthocyanins and a decrease in total acidity. Winkler Scale classifications (degree-days from budbreak to harvest) for the five vineyards have approximate values of 1380 to 2000. Thus the vineyards at 1415, 1350 m are in Regions I and II respectively, while the vineyards at 960 and 1160 m are in Region III and the vineyard at 774 m is in Region IV. Rainfall registered at meteorological stations from budbreak to harvest (2005 and 2006 vintages) ranged from approximately 450 to 980 mm. In general, it was concluded that Santa Catarina State is suitable for Cabernet Sauvignon growing.

Keywords: Brazilian Cabernet Sauvignon grapes, ripening, mesoclimate, vineyard altitude, phenology.

Introduction

It is well known that the great wines of the world are made in regions having correct climates for growing specific varieties of grapes. Terroir has been used to specify the general environment of vineyards and their wines; it takes into account terrain, altitude, climate, soil type, human activity, etc. Old world wines come from the classic wine making regions in Europe. Under the French Appellation d'Origine Controlée (AOC), terroir has become closely linked with quality. However, geographically distinct regions around the world have been evaluated for growing *Vitis vinifera* L. grapes for wine production. According to these evaluations, great wine regions can be found in North America, Latin America, South Africa, Australia and New Zealand. In these places, Cabernet Sauvignon grapes are one of the many varieties cultivated.

Research devoted to improving wine of this variety in Santa Catarina State, located at southern of Brazil, a new grape growing region of *Vitis vinifera* L. grapevines have been recently cultivated (5-6 years) at altitudes that can vary as much 700 m (asl).

Ideally, grapes are harvested when optimum levels of sugar, colour and acidity are reached. This work reports ripening parameters of Cabernet Sauvignon grapes from five young vineyards for the 2005 and 2006 vintages. These vineyards are planted on two soil types located at different altitudes in the Santa Catarina State, Brazil. Relationships between grape composition, the vineyard altitude, and the phenology events in the different sites were examined by principal component analysis (PCA) and Regression analyses.

Material and methods

Plant growth. The experiment was conducted in five vineyards at different altitudes in Santa Catarina State, South Brazil, on grapevines *V. vinifera* cv. Cabernet Sauvignon of 2005 and 2006 vintages from commercial vineyards having similar cultural practices. Data on the locations, altitudes, plant clones, conduction systems and soil types (U.S. soil taxonomy) are shown in Table 1. For all sites the row and vine spacing was of 3.0 *x* 1.5 m, respectively; the rootstock was Paulsen 1103 (*V. berlandierli* Planch *x V. rupestris* Scheele), the clone was R-5, the vineyard's yield was between 8 and 10 t/ha, the age of vines was between 5 and 6 years.

Site (Code)	Latitude	Longitude	Altitude[a]	Clone	VCS[b]	Soil Type
São Joaquim A (SJA)	28º16' 41"	49º55' 96"	1415	R-5	V	Inceptisol
Água Doce (AD)	26º43'30''	49º55'60''	1350	R-5	Vertical Trellis	Inceptisol
São Joaquim B (SJB)	28º19'0''	49º34'51''	1160	R-5	V	Inceptisol
Bom Retiro (BR)	27º53'5''	49º34'51''	960	685	Vertical Trellis	Inceptisol
Videira (VID)	27º0'14''	51º9'0''	774	R-5	V	Oxisols

Table 1 Locations and planting characteristics of the vineyards studied [a] Meters above sea level. [b] Vine Conduction System.

Phenology: Budbreak, floraison, véraison and harvest dates were recorded at each site.

Climate data. Mean daily temperatures were supplied by EPAGRI-SC (Empresa de Pesquisa e Extensão Agropecuária de Santa Catarina). Meteorological stations were located either within or in close proximity to the vineyards, except for the São Joaquim B site where a station located 4 km from the vineyard was used.

Berry samples and commercial maturity analysis: The sampling period began at véraison by visual assessment of when approximately 50 % of the berries attained a black colour. In general, 5-7 samples were collected at 10-day intervals from the five vineyards. In each vineyard, 30 vines in two central rows were selected for testing. A total of 240 berries were collected, eight berries per vine. Harvest began when each crop reached commercial maturity (TSS at 20-24 °Brix). Berry samples were rapidly collected, counted, weighed and submitted to physicochemical analyses. Each 240 berries sample was divided into 3 sub-samples (90, 90 and 60 berries). For berry maturity analysis, juice was squeezed from a fresh 30-berry sample randomly selected, in triplicate (= 90 berries). Juice samples were analyzed according OIV (1990) procedures for pH, titratable acidity (TA), total soluble solids (TSS, °Brix).

Index of precocity calculations: The method of Barbeau et al. (1998) was used. This phenological classification incorporates the values for floraison (IPF), véraison (IPV) and annual cycle (IPCY).
Measurements of berry composition
Anthocyanins extraction and quantification: Total monomeric anthocyanins (TMA) was determined by the pH-differential method of Giusti and Wrolstad (2001), using ε = 28000 and MW = 529 (Amerine and Ough, 1976).
Total polyphenol index (TPI): Folin-Ciocalteu assay was used and total phenolic content was expressed as Gallic acid equivalents (GAE) in milligrams per 100 gram of fresh grape skins.
Colour measurement: Tint, CI and d*A* (%) were calculated according Glories (1984) using a 1 mm pathlength cuvette.
Statistical analysis: Anova, Tukey HSD test, Principal Component Analysis (PCA), and Regression analysis were made using Statistica 6 (2001) (StatSoft Inc., Tulsa, OK, USA).

Results and Discussion

Phenology. The variation in dates of budbreak and floraison was considerably higher in 2006 vintage (Figure 1). Mid-budbreak date ranged from 02 September to 05 October in 2006, while in 2005 vintage it ranged from 14 to 30 September.

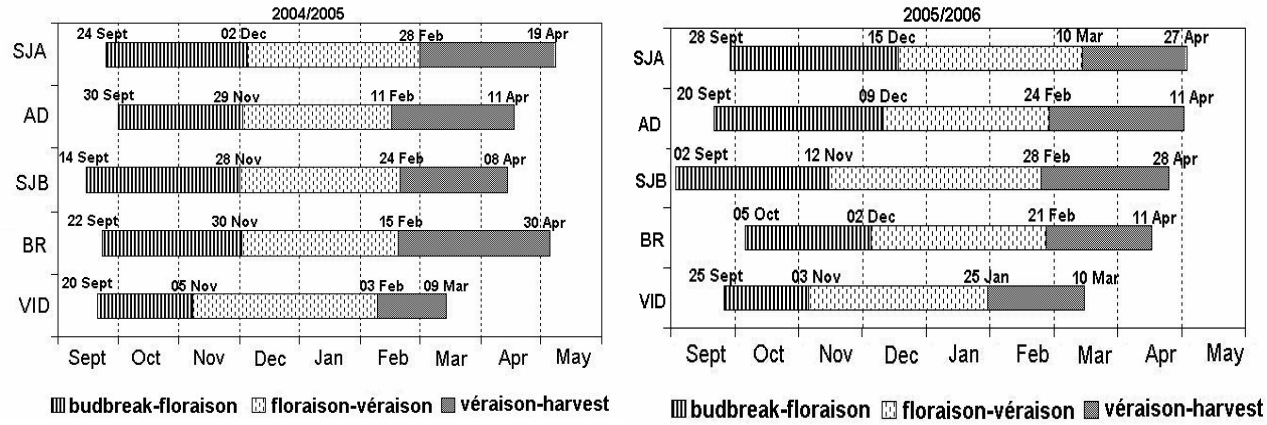

Figure 1 Phenological events duration in the different vineyards selected, for 2004/05 and 2005/06 vintages.

Two-year averages of the indices of precocity varied considerably for the five sites (Figure 2 A and B). All sited except to Videira gave late values compared to IPCY. São Joaquim A was the latest site and Videira was the earliest site (Figure 2 A). São Joaquim A showed the lowest variability between the indices of precocity. Thus, vineyard altitude appears to exert an important influence on IPF (R^2 = 0.7535), IPV (R^2 = 0.4564) and particularly on IPCY (R^2 = 0.8795). In addition, the mean air temperatures during the budbreak-harvest period can be correlated with IPF (0.9566), IPV (0.8155) and IPCY (0.9929), showing that at the higher sites the climate is colder; this retards the phenological stages (Figure 2 B). This finding differs from the results similar work on Cabernet Franc by Morlat (1992) who found no relation between air temperature of Loire Valley and site precocity.

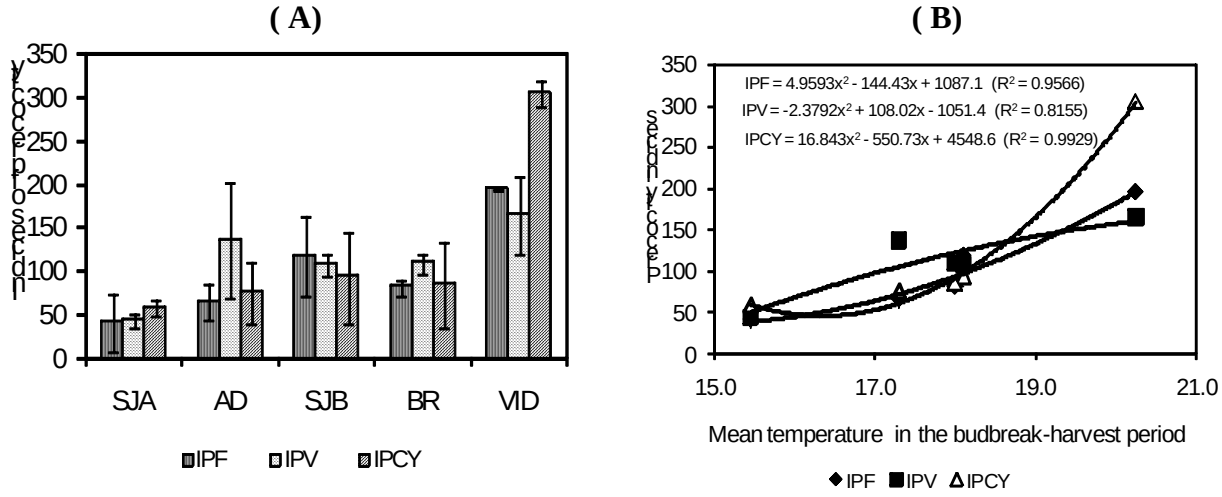

Figure 2 Indices of precocity (A) and relationship between them and the mean temperature of the air in the sites at different altitudes (B).

Berry development at maturity. At the commencement of ripening, in both vintages, the titratable acidity (TA) of grapes was the highest in the vineyards located at highest altitudes (1415 and 1350 m asl). Acidity dropped abruptly over the 10 first days of maturation in these sites in both vintages. At São Joaquim A this drop was 0.90 and 0.58 g/L for the 2005 and 2006 vintages, respectively while at Água Doce these differences were 0.65 and 0.42 g/L for these vintages.

With regard to TSS evolution in both vintages, São Joaquim B gave the high values during maturation period. In general, TMA reached the maximum concentration approximately 40 days after véraison. The evolution of total polyphenols index (TPI) in the grapes skins varied considerately between the sites evaluated. In the 2005 vintage, TPI reached the maximum content reach at harvest. With regard to Glories parameters evolution, it is clear that not only Abs 520 nm contributed for grape skins colour; Abs 420 nm and Abs 620 nm indices were also responsible.

Table 2 gives the results of berry composition analyses at maturity. In 2005 the TA for all sites was similar. For the 2006 vintage, there is a positive relationship between elevation and TA. In 2006, TA values were lower than 2005 vintages only for Bom Retiro and Videira berries. Total soluble solids (TSS) values were not significantly different over the sites evaluated ($p<0.05$) in 2005 vintage, while the maturation indices (MI) was higher for grapes cultivated at the highest altitudes. Anthocyanin content and colour intensity were significantly lower for the Videira berry skins ($p<0.05$). In both vintages, São Joaquim B berries have the highest TSS content while São Joaquim A gave the higher berry weight.

PCA was carried out on the correlation matrix using the mature berry composition data for the two vintages (Figure 3 A and B). Figure 3A gives the 2005 results, where the axes Factor 1 *x* Factor 2 explains 78.27 % of the total variance among the data. The first axis represents 52.39 % and the second axis, 25.88 % of the total dispersion. TSS, pH, MI, Abs 520 nm and Abs 620 nm were strongly positively correlated with Factor 1. Abs 420 nm and CI were strongly positively correlated with two axes. Tint and TPI were positively correlated with Factor 1 and negatively correlated with Factor 2. TA and berry weight were strongly negatively correlated with Factor 1; berry weight was also strongly positively correlated with Factor 2. From this analysis of the 2005 data, TA and berry weight, were strongly negatively correlated with pH. Projection of the variables showed that TSS was strongly negatively correlated with berry weight and TA. Also, TA was strongly negatively correlated with MI, TPI and Glories parameters.

	São Joaquim (A)	*Água Doce*	*São Joaquim* (B)	*Bom Retiro*	*Videira*
Altitude sea level (asl)	*1415 m*	*1350 m*	*1160 m*	*960 m*	*774 m*
Soil type	*Inceptisols*	*Oxisols*	*Inceptisols*	*Inceptisols*	*Oxisols*
2005 vintage					
pH	3.60 ± 0.09 a	3.79 ± 0.05 b	3.80 ± 0.00 b	3.73 ± 0.03 b	3.59 ± 0.05 c
TSS (°Brix)	21.35 ± 0.07 a	22.5 ± 0.36 a	23.0 ± 0.71 a	22.5 ± 0.50 a	21.67 ± 0.29 a
Titrable acidity (TA)	0.75 ± 0.03 a	0.65 ± 0.02 b	0.67 ± 0.00 c	0.76 ± 0.02 c	0.85 ± 0.00 c
Maturation index (TSS/TA)	29 ± 1.00 a	35 ± 0.40 b	34 ± 1.06 b	29 ± 0.50 c	26 ± 0.31 a
Weight of 200 berries (g)	296	280	284	274	292
Total monomeric anthocyanins (TMA)*	365 ± 0.40 a	379 ± 1.41 b	380 ± 17.68 b	401 ± 1.41 c	310 ± 0.29 d
Total polyphenol index (TPI)**	653 ± 6.14 a	906 ± 12.40 b	727 ± 52.72 a,b	890 ± 46.52 b	757 ± 85.29 a,b
Abs 420 nm	1.007 ± 0.02 a	1.153 ± 0.01 b	1.246 ± 0.02 c	1.067 ± 0.00 a	0.733 ± 0.01 d
Abs 520 nm	2.276 ± 0.01 a	3.223 ± 0.00 b	3.016 ± 0.01 a	2.850 ± 0.02 c	1.833 ± 0.02 d
Abs 620 nm	0.293 ± 0.01 a	0.180 ± 0.01 b	0.337 ± 0.00 c	0.169 ± 0.01 d	0.137 ± 0.00 e
Tint (Abs 420/Abs 520)	0.317 ± 0.00 a	0.359 ± 0.02 b	0.410 ± 0.01 c	0.377 ± 0.03 d	0.394 ± 0.01 e
Colour intensity (Abs 420 nm + 520 nm + 620 nm)	3.576 ± 0.01 a	4.556 ± 0.01 b	4.598 ± 0.01 b	4.086 ± 0.02 c	2.703 ± 0.02 d
d*A* (%)	71	79	74	78	80
2006 vintage					
Maturation period (days)	49	54	59	52	54
pH	3.42 ± 0.02 a	3.45 ± 0.02 a,b	3.55 ± 0.04 b,d	3.85 ± 0.02 c	3.57 ± 0.01 d
TSS (°Brix)	21.83 ± 0.15 a	20.77 ± 0.25 a	24.17 ± 0.55 b	20.17 ± 0.38 a	21.03 ± 0.06 a
Titrable acidity (TA)	0.95 ± 0.03 a	0.90 ± 0.06 a,b	0.87 ± 0.07 a,b	0.70 ± 0.02 b,c	0.59 ± 0.02 c
Maturation index (TSS/TA)	23 ± 1.03 a	23 ± 2.00 a	28 ± 1.17 a,b	29 ± 1.12 b,c	36 ± 1.20 c
Weight of 200 berries (g)	335	292	254	294	325
Total monomeric anthocyanins (TMA) *	421 ± 14.60 a	477 ± 4.50 b	392 ± 1.00 c	304 ± 0.71 d	332 ± 2.08 e
Total polyphenol index (TPI) **	639 ± 18.35 a	766 ± 10.40 b	761 ± 15.95 b	621 ± 35.10 a	782 ± 8.03 c
Abs 420 nm	0.967 ± 0.03 a,b	1.133 ± 0.01 a	0.937 ± 0.02 a,b	0.667 ± 0.02 c	0.903 ± 0.01 b
Abs 520 nm	2.999 ± 0.04 a,b	3.406 ± 0.04 a	2.769 ± 0.02 b	1.603 ± 0.06 c	2.569 ± 0.05 b
Abs 620 nm	0.107 ± 0.01 a	0.137 ± 0.00 a,b	0.107 ± 0.00 a	0.133 ± 0.00 a	0.173 ± 0.00 b
Tint (Abs 420/Abs 520)	0.319 ± 0.03 a	0.328 ± 0.02 a,b	0.341 ± 0.03 b,c	0.414 ± 0.01 d	0.348 ± 0.00 c
Colour intensity (Abs 420 nm + 520 nm + 620 nm)	4.073 ± 0.08 a,b	4.676 ± 0.05 a	3.813 ± 0.04 b	2.333 ± 0.08 b	3.645 ± 0.07 c
d*A* (%)	83	82	81	76	80

*Expressed in mg of malvidin-3-glusoside/100 g of grape skins; **Expressed in mgGAE/100 g of grape skins.

Table 2 Results of repeated measures on berry composition at maturity for 2005 and 2006 vintages.

Glories parameters revealed a strong positive correlation with MI, indicating that these parameters providing a very useful support for grape maturity evaluation. For both vintages, the projection of the cases on the two first axes shows that all the grape growing sites were clearly separated on the two first Factors of PCA (Figure 3 A and B). In 2005, São Joaquim A was positively correlated with berry weight, which confirms the results from Table 1. Água Doce and São Joaquim B, placed on the positive quadrant of the Factor 1, were the two vineyards closer to the two first axes of PCA. This has been more associated with Abs 420 nm, Abs 620 nm and MI. In both vintages, Bom Retiro berries at maturity appear to be strongly associated with TPI and tint.

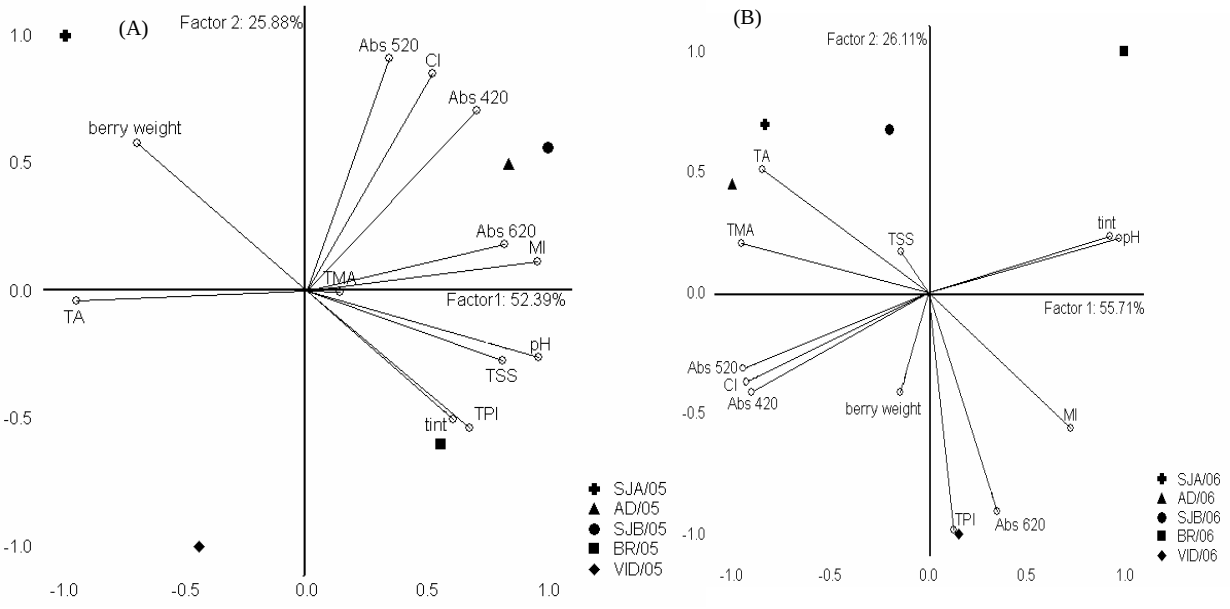

Figure 3 PCA on berries composition results at harvest in the 2005 (A) and 2006 (B) vintages.

In 2006 vintage, Factor 1 and Factor 2 explains 55.71% and 26.1% of the total variance, respectively (Figure 2B). Tint and pH were strongly positively correlated with Factor 1. TA and MI separation is even higher (over 180°) in the 2006 vintage. TA was strongly negatively correlated with Factor 1 and strongly positively correlated with Factor 2, while MI gave an opposite correlation with these two axes. TMA was strongly negatively correlated with Factor 1 while CI has been strongly positively correlated. In both vintages, a strong positive correlation was perceived between MI and TPI values. There is a weak negative correlation between TMA and berry weight in 2005; this correlation is stronger for 2006. Also, for both vintages, there was a negative correlation between TMA and pH values, particularly for 2006. Berry weight was also negatively correlated with TSS. Except to tint, TMA was strongly positively correlated with all the others Glories parameters. Projections for the three higher sites for 2006 are all in the negative quadrant of Factor 1, indicating that the data are similar. Videira berries correlated strongly with TPI and Abs 620 nm. In conclusion, grapes from vineyards placed at higher altitudes (1350 and 1415 m asl) had higher acidity at maturity.

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