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RESEARCH PAPER

Phenology and ripening of *Vitis vinifera* L. grape varieties in São Joaquim, southern Brazil: a new South American wine growing region

Eliana F. Gris[1], Vívian M. Burin[1], Emilio Brighenti[2], Hamilton Vieira[2], and Marilde T. Bordignon-Luiz[1]

[1]Departamento de Ciência e Tecnologia de Alimentos CAL/CCA; Universidade Federal de Santa Catarina. Rodovia Admar Gonzaga, 1346, Itacorubi, Florianópolis, SC, Brazil.

[2]EPAGRI Empresa de Pesquisa e Extensão Agropecuária de Santa Catarina. Rodovia SC 438, Km 70. São Joaquim-SC, Brazil.

Abstract

E.F. Gris, V.M. Burin, E. Brighenti, H. Vieira, and M.T. Bordignon-Luiz. 2010. Phenology and ripening of *Vitis vinifera* L. grape varieties in São Joaquim, southern Brazil: a new South American wine growing region. Cien. Inv. Agr. 37(2): 61-75. This study investigated the phenology and the ripening characteristics of *Vitis vinifera* grapes Cabernet Franc, Merlot, Sangiovese and Syrah in two consecutive vintages (2006 and 2007) in order to evaluate the adaptation of these recently cultivated varieties in São Joaquim, Santa Catarina State, Brazil. The phenological data observed, budburst, blooming, setting, véraison and harvest were monitorated. In order to monitor the ripening levels of pH, total acidity, total soluble solids, maturation index, total monomeric anthocyanins, total polyphenols index and color index were analyzed.The results show that the phenological cycle from budburst to harvest occurred within a frame time of 191 and 219 days and the heat summation requirements varied between 1,161 and 1,340 GDD. The summing of the GDD results during the phenological cycle of the grapevines (budburst - harvest) characterizes São Joaquim-SC as "Region I" (< 1,389 GDD), that is, a "cold region" in terms of the Winkler Regions.The climatic parameters influenced the grapevine phenology and the grape ripening. The results showed that these different grape varieties had typical characteristics at maturity and indicated that they have potential for the production of fine wines, suggesting that São Joaquim-SC is suitable for *Vitis vinifera* grape growing.

Key words: *Vitis vinifera* L., climatic parameters, grapes, phenology, ripening.

Introduction

The French term 'terroir' is used to describe the ambience created by the soil and its immediate environment. Topographical, geographical, morphological, and agro-pedological factors, if it is maintained, influence quality and can define boundaries of appellations recognized as producing superior wines. While the precise contribution of each factor may not be known, experience indicates that a good terroir will encourage slow, but complete, maturation of appropriate grape cultivars. In general, a good terroir is one which limits the climatic extremes that may occur from year to year. Recent research in São Joaquim Region, Santa Catarina State, Brazil, has attempted to assess the poten-

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Corresponding author: elianagris@yahoo.com.br

tial of this region in terms of grape production and wine quality (Gris *et al*., 2007; Falcão *et al*., 2007; Falcão *et al*., 2008a).

São Joaquim-SC is a new wine growing region located in the high plains of Santa Catarina State. It is known in Brazil as the coldest place in the country, and has a later budbreak and ripening in relation to other viticulture regions in Brazil (Gris *et al*., 2008). The altitude (800 – 1400 m), is a factor which can strongly affect the climatic conditions, since it directly influences the temperature, humidity and other environmental factors which affect the grapevine phenology and the grape maturation (Mateus *et al*., 2002).

Phenology is the study of the individual physiological events or growth stages of plants or animals that recur seasonally in response to the climate. Understanding the phenology of a given plant system is important for determining the ability of a region to produce a crop within the confines of its climatic regime (Morlat and Bodin, 2006; Webb *et al*., 2007).

Vitis vinifera grapevines are a phenologically distinct crop with the most important development stages being budburst, blooming (flowering), setting (fruit set), véraison (color change and beginning maturation) and harvest (grape maturity). The time between these phenological stages varies greatly with grapevine variety, climate, and geographical location (Bodin and Morlat, 2006; Webb *et al*., 2007). Timing of these developmental stages is also related to the ability of the vine to yield fruit, with early and fully expressed phenological events usually resulting in larger yields (Davies and Jones, 1998; Leewen *et al*., 2004). Grape ripening encompasses the period that starts with the color change and ends at harvest, and varies according to the variety and the region. The main modifications that occur in the berries and, therefore, in the composition of the grape during the ripening are: an increase of the berry volume, hormonal variation, sugar accumulation, acidity reduction, pH increase, disappearance of chlorophyll and pigment accumulation in the skin, softening of the berries, synthesis of aromatic substances and flavor modification (Jackson and Lombard, 1993; Serrano-Megías *et al*., 2005; Mota *et al*., 2006).

Many factors influence the grape ripening, the mains ones being: a) the permanent factors which are constant and do not vary from one year to the next, that is, the region, the soil, the variety, and the rootstock; b) changeable factors which are related to the annual climate (temperature, precipitation, light and humidity) and establish the rhythm of the vegetative cycle of the plant; c) modifiable factors relating to cultivation practices, such as the fertilizer application, the pruning, the irrigation; d) the accidental factors including incidence of disease and climatic alterations such as frost, hail and drought (Smart, 1985; Bodin and Morlat, 2006).

The monitoring of ripening through classic analysis of pH, total acidity and total soluble solids, as well as the evaluation of phenolic compounds (anthocyanins and polyphenols) is very important to control the berry development and maturation. When introducing new grape varieties, the phenology and ripening monitoring is important in determining the ability of a region to produce a crop within the confines of its climate regime. In this study the phenology and ripening of the *V. vinifera* varieties Cabernet Franc, Merlot, Sangiovese and Syrah, recently cultivated in São Joaquim-SC, were monitored, in order to characterize their adaptation to this new grape growing region.

Materials and methods

Characterization of São Joaquim – SC region

The region of São Joaquim is located in Santa Catarina State at altitudes of 800 - 1400 m, coordinates 28º lat. and 49º long., and these are the highest altitudes of vineyards in Brazil. The soil of this region is of the type Humic Aluminic Cambisoil (with a medium clay texture) It is a well drained soil with a soft friable consistency, a high capacity for water retention and an absence of stones (Falcão et al. 2008a). According to the Geoviticulture Multicriteria Climatic Classification System (Tonietto and Carbonneau, 2004) the weather of the São Joaquim-SC region is classified as "Cool, Cool nights and Humid": Huglin's heliothermal index-HI: 1,714; cool night index: 12.1 ºC (index developed as an indicator of night temperature conditions during maturation); and dryness index-DI: 200 mm, humid (index corresponding to the potential water balance of the soil of Riou's index, adapted using precise conditions to calculate it, as an indicator of the level of presence-absence of dryness).

Climatic parameters

Climatic data were obtained from a meteorological weather station located at 1000 m (EPAGRI - CIRAM (Agricultural Research Agency), Santa Catarina State, Brazil). The data comprise daily observations of maximum (T_{max}), minimum (T_{min}) and medium (T_{med}) temperatures, insolation, precipitation, wind strength and photoperiod. These general climatic parameters were used to derived other variables used in viticulture studies, including thermal amplitude (cumulative daily air temperature difference – maximum minus minimum), estimated potential evapotranspiration (ET_0 - Thornthwaite method) and heat summation requirements, were observed for a growing degree-days base of 10 ºC (GDD= $\sum (T_{> 10\,ºC} - 10\,ºC)$) (Winkler, 1980).

Plant material

This experiment was conducted during two consecutive vintages (2006 and 2007) in a commercial vineyard at 28º 15' lat., 49º 50' long. and 1,290 m altitude. The vines of the varieties Cabernet Franc, Merlot, Sangiovese and Syrah were planted in 2003, and the clones used were 986, 181, VCR23 and VCR1, respectively. The rootstock used was Paulsen 1103 (*V. berlandieri* Planch x *V. rupestris* Scheele); the vertical shoot positioning trellis system training was used; the row and vine spacing was 3.0 x 1.2 m and the vineyard yield was between 6 and 7 t/ha.

Phenology

Data on the occurrence of budburst, blooming, setting, véraison and harvest dates for the varieties Cabernet Franc, Merlot, Sangiovese and Syrah, 2006 and 2007 vintages, were noted. The budburst, blooming, setting and véraison events are considered to occur when, for a given varietal, 50% of the plants exhibit the physiological response. Harvest date is recorded as the point at which, owing to optimal sugar levels, the first day of grape harvest commences for a given varietal.

Grapes ripening analysis

The whole study during the two consecutive vintages was conducted carefully with the same procedure, aiming to ensure sample homogeneity. The monitoring of the ripening of *V. vinifera* Cabernet Franc, Merlot, Sangiovese and Syrah grapes began at the véraison when approximately 50 % of the berry had turned red. The samples were collected at intervals of 10 days. Each sample consisted of a total of 240 berries, with 8 berries per vine. The berry weight (BW) was determined through the average weight of 100 berries.

For the grapes ripening analysis, juice was squeezed from a fresh 30 berry, randomly selected, in triplicate. The samples were analyzed according to OIV (1990) procedures for pH (pH meter - MP 220 meter, Metler, Toledo), titratable acidity (TA) (titration with 0.1 M NaOH), total soluble solids (TSS, °Brix), using an Abbe refractometer at 25°C (AusJena, model 265085). Maturation index (MI) was obtained from the TSS/TA ratio.

For quantification of the grapes phenolic content the extract used was obtained as follows: grape skins were carefully removed from 90 berries and used for the extraction process of the phenolic ripening analysis. A precisely weigh amount of skins was homogenized in extraction solvent in order to obtain a proportion of 100 g of skins in 400 mL extraction solvent (methanol:HCl ratio of 99:1). The homogenate was allowed to stand at 4 ± 1 ºC in the dark for 24 h. The methanolic extract obtained was filtered through a nylon filter and the remains of the skins were washed with 100 mL of extraction solvent (Lees and Francis, 1972). Vaccum filtration was carried out using Whatman no. 2 filter papers in a Büchner funnel. Quantification of total monomeric anthocyanins (TMA) was carried out applying the pH-differential method according to Giusti and Wrolstad (2001), using ε= 28000 and MW= 529 (Amerine and Ough, 1976). The total polyphenols index (TPI) was determined at 280 nm according to Riberéau-Gayon (1970). The color intensity was determined by optical density measuring at three wavelengths, 420, 520 and 620 nm, using a 1 mm-pathlength cuvette. The intensity was the sum of the three absorbance values and the tonality was obtained at 420/520 nm (Glories, 1984). These analyses were carried out by spectrophotometric methods using a Hitachi U2010 spectrophotometer (CA, USA).

Statistical analysis

All analysis was carried out with two repetitions in triplicate. Linear regression, analysis of variance (ANOVA), principal components analysis (PCA) and the Tukey HSD Test were performed using Statistica 6 (2001) (Statsoft, Tulsa, OK, USA) and Origin (2001). The probability level used was $p \leq 0.05$.

Results and discussion

Climatic parameters

The climate is one of the basic aspects in the grape culture and, consequently, for the viticulture. Viticulture for the wine production is developed in many types of climate and soil in the different continents (Tonietto and Carbonneau, 2004). A survey of world viticultural areas can indicate relationship between climate and quality (Jackson and Lombard, 1993). Thus, the monitoring of the climatic parameters are important because these influence both grape and wine quality.

The values for climatic parameters obtained during 2006 and 2007 vintages are shown in Table 1. In general, it was verified that these parameters were appropriate for the required phenological development of the grapevines and the grape ripening during the two vintages evaluated. The photoperiods were similar for the two vintages (3,170 in 2006 and 3,194 in 2007).

The temperature influences many parameters, including acidity level, pH, flavor and aromatic components, sugar and polyphenols; warmer temperatures almost invariably result in grapes with higher total soluble solids content (Jackson and Lombard, 1993). Thermal amplitude (cumulative daily air temperature difference between maximum and minimum) is the most reliable indicator for the time between bloom and maturity; it seems to successfully incorporate a number of different environmental circumstances (McIntyre *et al*., 1982). The thermal amplitude verified is consistent with that recommended by Brighenti and Tonieto (2004) who reported that around 10 ºC can be considered an excellent thermal amplitude. In general, the temperature values observed in our study were suitable for the phenology and ripening of the grapes. For the 2007 vintage this value was higher than for the 2006 vintage.

The insolation values were appropriate for the grapevine phenology and grape ripening (1200 - 1400 hours during the phenological cycle) (Manica and Pommer, 2006). For the 2006 vintage this value was higher than for the vintage 2007. The monitoring of this parameter is important because insolation influences the photosynthetic activity, and consequently, the satisfactory development of the fruit (Calò *et al*., 1996). Many authors affirm that the insolation also stimulates berry anthocyanin accumulation (Smart, 1985; Keller and Hrazdina, 1998; Leewen *et al*., 2004).

The precipitation values observed during the two vintages (Figure 1, Table 1) can be considered normal for the stages of budburst and blooming, in terms of promoting adequate inflorescence differentiation and berry set (Jones

Table 1. Climatic parameters: minimum temperature (T_{min}), maximum temperature (T_{max}), medium temperature (T_{med}), thermal amplitude and temperature at 21 h (T 21 h), wind strength (WS), photoperiod, insolation, precipitation (Precip) and evapotranpiration (ET_0) summation obtained from metereological station at São Joaquim SC, during the budburst at harvest vintages 2006 and 2007 for varieties evaluated. Data are average values for the phenological period.

	Burdburst/ Blooming		Blooming/ Setting		Setting/ Véraison		Véraison/ Harvest		Burdburst/ Harvest	
	Vintages		Vintages		Vintages		Vintages		Vintages	
Climatic Parameters	2006	2007	2006	2007	2006	2007	2006	2007	2006	2007
T min. (º C)	8.6	9.5	10.3	11.1	12.1	12.5	12.1	13.8	10.9	12.1
T max. (º C)	17.3	19.4	20.4	21.2	22.1	22.4	21.3	22.3	20.3	21.5
T med. (ºC)	12.3	13.7	14.6	15.4	16.2	16.7	15.6	17.2	14.7	16.0
Amplitude (º C)	8.8	10.0	10.1	10.2	10.0	9.8	9.2	8.5	9.4	9.3
T 21 h (º C)	11.6	12.7	13.5	14.2	15.1	15.6	14.8	16.2	13.8	15.0
WS (km/h)	2.53	2.86	2.14	2.53	1.98	2.35	1.85	2.02	2.13	2.32
Photoper. (hours)	917	848	950	889	1,633	1,620	937	919	3,170	3,194
Insolation (hours)	477	524	443	410	759	706	448	399	1,400	1,375
Precip. (mm)	611	418	254	278	415	561	92	449	1,004	1,137
ET_0 (mm)	203	208	242	179	348	314	224	229	637	668

and Davies, 2000). However, during the ripening of the 2007 vintage the frequency and amount of precipitation were atypically high for the period (Figure 1B), due to the presence of cold front weather systems (data not shown). High precipitation values are not recommended because rainfall, when associated with adverse weather, may aggravate moisture-related problems (Calò *et al.*, 1996; Jones *et al.*, 2005).

Water use is often estimated from the evapotranspiration (Esteban *et al.*, 2002; Dragoni *et al.*, 2006). Jones and Davies (2000) affirm that evapotranspiration influences the acidity levels in the grapevine. In our study the values were 637 and 668 mm for the 2006 and 2006/2007 vintages, respectively, the 2007 vintage having slightly higher water consumption than the preceding vintage. This probably occurred due to high precipitation values recorded for this vintage (Table 1). The values obtained in this study are consistent with those of Bodin and Morlat (2006) who evaluated the potential evapotranspiration in the Anjou vineyard (France), and with other researches. Intrigliolo and Castel (2008) found that the vine water consumption is variable and influenced by climatic conditions, seasons and sites.

The Winkler index is calculated for the period of budburst through to harvest by summing each day's average temperature above a base value of 10 ºC, the minimum temperature at which vine growth occurs (Winkler, 1980). It is widely used as a guide for the selection of appropriate grape varieties and for determining the suitability of a given area to produce quality wine grapes (Jones et al., 2005). Although it is limited because it only considers the temperature, it is widely used because the temperature is a determining factor in the phenology (Jones and Davies, 2000; Spellman, 1999). The summed GDD results during the phenological cycle *(*burdburst - harvest*)* of the grapevines characterized São Joaquim-SC as "Region I"

(< 1,389 GDD), that is a “cold region” in terms of the Winkler Regions (Figure 2). Similar results were verified by Jones *et al*. (2005) for the regions of Puget Sound (U.S.A.).

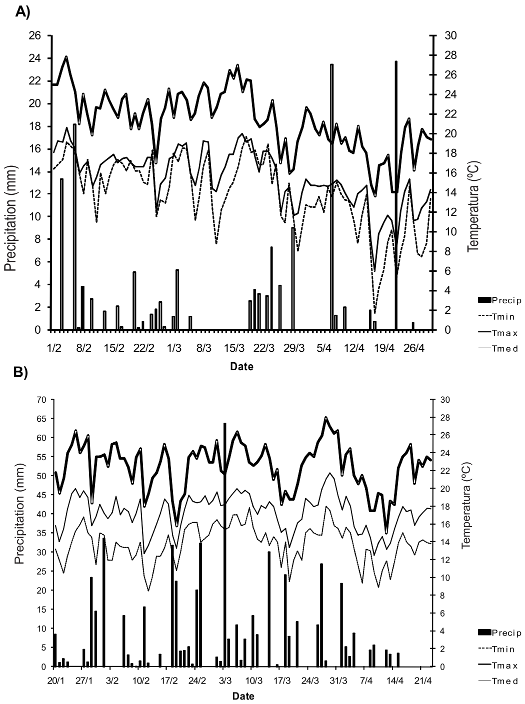

Figure 1. Maximum, medium and minimum temperatures and the precipitation values during véraison to harvest, year 2006 (vintage 2006) (A) and year 2007 (vintage 2007) (B).

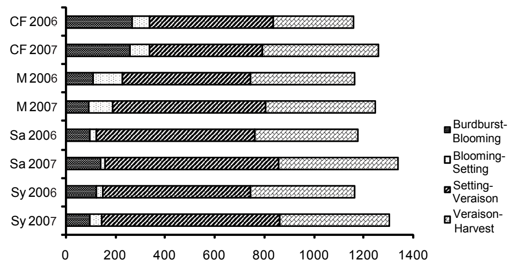

Figure 2. Heat summation requirements (GDD: growing degree-days base 10 ºC) from budburst to the main phenological periods for the varieties evaluated, vintages 2006 and 2007. CF= Cabernet Franc, M= Merlot, Sa= Sangiovese, Sy= Syrah.

Phenology

For the two evaluated vintages, the grapevine budburst period began in winter, between 30/08 and 30/09. For the 2006 vintage it was observed that the budburst began earlier than for the 2007 vintage, and the interval between budburst/blooming was longer (Table 2). The Sangiovese cultivar was the most precocious and Cabernet Franc the latest. The heat summation requirements of the varieties during the period between budburst and blooming varied from 96 to 271 GDD, the Cabernet Franc variety requiring the greatest number of days and the greatest heat summation for this period (Figure 2 and 3).

The blooming phenological phase occurred between 18/10 and 30/11 for the two evaluated vintages, i.e., in the spring (Table 2). The blooming/setting interval showed mean temperatures of around 14.6 - 15.5 ºC, and precipitation in the range of 254 - 278 mm. This period presented the lowest heat summation requirements, between 15 and 93 GDD, and shortest time, between 8 and 29 days (Figures 2 and 3). The Sangiovese blooming/setting period was significantly shorter when compared with the other varieties evaluated, and consequently there was a lower heat requirement. Merlot had the longest blooming/setting period compared with the other varieties. The varieties Cabernet Franc and Merlot showed the greatest heat summation requirements. Following the trend from the beginning of budburst, the most precocious variety was Sangiovese and the least Cabernet Franc for both vintages.

Setting/véraison was the phenological period with the longest duration (51 - 103 days) and greatest heat summation requirements (453 -717 GDD). This occurred between 27/10 and 21/02. For the 2007 vintage this phenological interval had a greater duration and heat summation requirements when compared with the previous vintage, except for the Cabernet Franc variety.

T**able 2.** Start dates for beginning of phenological events for the varieties evaluated (Cabernet Franc, Merlot, Sangiovese and Syrah), for two consecutivies vintages 2006 and 2007, in São Joaquim-SC.

Phenological events	Vintages	Cabernet Franc	Merlot	Sangiovese	Syrah
Budburst	2006	20/09	15/09	30/08	15/09
	2007	30/09	20/09	06/09	25/09
Blooming	2006	30/11	25/10	19/10	28/10
	2007	28/11	21/10	18/10	24/10
Setting	2006	24/12	23/11	31/10	13/11
	2007	19/12	20/11	27/10	09/11
Véraison	2006	19/02	06/02	07/02	18/02
	2007	07/02	08/02	06/02	18/02
Harvest	2006	22/04	19/04	21/04	20/04
	2007	09/04	11/04	18/04	21/04

The beginning of the ripening occurred between 06/02 and 21/02, i.e., in the summer. The véraison/harvest period was from 58 to 73 days and required heat summation ranged from 325 - 482 GDD. The harvest occurred between 03/04 and 20/04 (autumn), a period historically with a low precipitation index, which is considered very desirable for the health of the grapes and production of quality fine wines. Atypically, during the previous period of ripening of the 2007 vintage (véraison-harvest) the frequency and amount of precipitation could be considered high for the period (Figures 1B, Table 1).

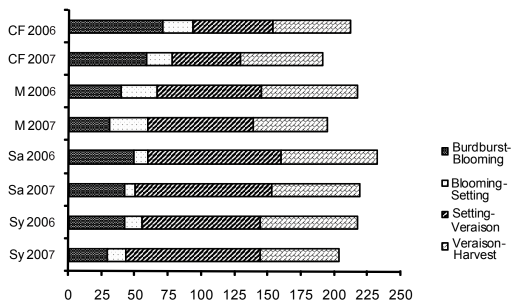

Figure 3. Number of days from budburst to the main phenological periods for the varieties evaluated, vintages 2006 and 2007. CF= Cabernet Franc, M= Merlot, Sa= Sangiovese, Sy= Syrah.

The phenological cycles (budburst/harvest) were from 191 to 219 days and required heat summation of 1,161 - 1,340 GDD; the most precocious variety with the longest phenological cycle (days) was Sangiovese and the latest variety with the shortest phenological cycle (days) was Cabernet Franc, for both vintages. The heat summation requirement for the varieties evaluated characterizes São Joaquim-SC town as "Region I" (< 1,389 GDD), that is a "cold region" on the Winkler scale.

The phenological cycle (Table 1 and 2, Figure 2) of the 2006 vintage had a longer duration, but lower heat summation requirement. The greater heat summation requirement of the 2007 vintage was probably due to the higher average temperatures compared with the previous vintage which generally causes an anticipation of the occurrence of the phenological events, as was observed for all phenological events, except budburst. The same results have been reported by other researchers (Bindi *et al*., 1996; Van Leeuwen *et al*., 2004; Roberto *et al*., 2005). Jones *et al.* (2005) reported what Sangiovese cultivated in the Conegliano region, Italy, between 1964 and 2004, had a heat summation requirement of 1,803 GDD and phenological cycle of the 163 days. Falcão et al. (2007) observed that the heat summation requirement ranged from approximately 1,400 to 2,000 GDD for Cabernet Sauvignon grapes, depending on the growing region.

Differences can be observed between the climatic data of the two vintages (Table 1, Figures 1 A and B). The maturation period of the 2007 vintage had higher precipitation values, atypical of the region, and also higher temperature values in relation to the other vintage, resulting in higher GDD values. The values for temperature, thermal amplitude, and insolation hours were suitable during maturity, which is important for the adequate growth of the grapes. The temperature and insolation hours directly influenced the sugar concentration and the phenolic maturity (Smart, 1985; Mota *et al*., 2006).

Berry chemicals parameters

The total soluble solids (TSS) of the varieties for the 2006 and 2007 vintages are shown in Figure 4. The TSS values differed for the two vintages, except for the Cabernet Franc (Table 3). Among the varieties analyzed Syrah was differentiated from the others ($p= 0.005$), with lower TSS values (20.4 and 19.0 ºBrix) for both vintages. All the varieties show TSS values suitable for the production of quality wine, between 19.0 and 25.0 ºBrix. Positive correlation ($R= 0.62$) was observed between the ºBrix values and photoperiod during the grape maturity for the two vintages evaluated, indicating that an increase in hours of natural light stimulates the production of sugars in the grape. This happens because photoperiod influences the photosyntheses directly and consequently the sugar production in the grapes (Manica and Pommer, 2006).

According to the OIV (1990), the Cabernet Franc, Merlot and Syrah grapes can be considered 'small berry ' (< 2.0 g), and the Sangiovese grapes 'intermediate berry' (2.0-2.5 g) for the 2006 vintage and 'large berry' (2.5- 3.5 g) for the 2007 vintage (Table 3), due to the higher precipitation for this vintage.

Table 3. Results for berry weight (BW), total soluble solids (TSS or ºBrix), titratable acidity (TA), pH, maturation index (MI), total monomeric anthocyanins (TMA), total polyphenols index (TPI), Abs 420 nm, Abs 520 nm, Abs 620 nm, tonality (420/520 nm) and color index (CI) for grapevines at harvest for 2006 and 2007 vintages.

	Cabernet Franc	Merlot	Sangiovese	Syrah
Vintage 2006				
BW (g)	1.40 ± 0.05 a	1.53 ± 0.09 b	2.19 ± 0.08 c	1.53 ± 0.11 b
SST (º Brix)	23.8 ± 0.35 a	24.2 ± 0.21 a	24.2 ± 0.1 a	20.4 ± 0.11 b
TA*	0.59 ± 0.03 a	0.57 ± 0.02 a	0.81 ± 0.03 b	0.65 ± 0.01 c
pH	3.46 ± 0.04 a	3.53 ± 0.01 a	3.31 ± 0.03 b	3.41 ± 0.06 b
MI	40.5 ± 0.2 a	42.4 ± 0.15 b	29.9 ± 0.06 c	31.6 ± 0.6 d
TMA**	426.7 ± 1.8 a	677 ± 2.6 b	369.7 ± 2.9 c	615.8 ± 3.5 d
TPI	51.6 ± 1.15 a	84.9 ± 0.5 b	45.5 ± 1.3 c	91.1 ± 0.5 d
Abs 420 nm***	6.51 ± 0.2 a	16.95 ± 0.3 b	5.89 ± 0.1 c	13.29 ± 0.3 c
Abs 520 nm***	26.56 ± 0.3 a	50.54 ± 0.4 b	13.98 ± 0.2 c	33.76 ± 0.4 c
Abs 620 nm***	4.23 ± 0.1 a	2.08 ± 0.1 b	0.83 ± 0.03 c	3.13 ± 0.09 c
Tonality	0.24 ± 0.01 a	0.33 ± 0.02 b	0.42 ± 0.01 c	0.39 ± 0.01 c
CI***	37.3 ± 2.6 a	69.5 ± 2.4 b	20.7 ± 1.2 c	50.2 ± 2.0 d
Vintage 2007				
BW (g)	1.55 ± 0.20 a	1.92 ± 0.10 b	3.05 ± 0.20 c	1.78 ± 0.15 d
SST (º Brix)	23.3 ± 0.28 a	22.5 ± 0.1 b	21.3 ± 0.3 c	19.1 ± 0.12 d
TA*	0.63 ± 0.01 a	0.64 ± 0.01 a	0.75 ± 0.01 b	0.63 ± 0.01 a
pH	3.58 ± 0.04 a	3.56 ± 0.02 a	3.5 ± 0.02 a	3.52 ± 0.03 a
MI	36.4 ± 0.11 a	34.6 ± 0.09 b	28.11 ± 0.1 c	30.25 ± 0.3 d
TMA**	860 ± 30,9 a	567.9 ± 2,2 b	352.1 ± 7,4 c	864.6 ± 7.3 a
TPI	119.3 ± 0,7 a	78.2 ± 1,2 b	57.3 ± 1,5 c	126.1 ± 3,1 d
Abs 420 nm***	21.04 ± 0.18 a	14.34 ± 0.1 b	9.35 ± 0.09 c	22.34 ± 0.17 a
Abs 520 nm***	57.23 ± 0.45 a	39.67 ± 0.26 b	22.83 ± 0.16 c	58.85 ± 0.42 a
Abs 620 nm***	3.43 ± 0.02 a	1.82 ± 0.11 b	1.09 ± 0.05 c	4.34 ± 0.02 d
Tonality	0.37 ± 0.01 a	0.36 ± 0.01 a	0.39 ± 0.02 a	0.37 ± 0.01 a
CI***	81.7 ± 3,6 a	55.9 ± 2,1 b	33.3 ± 1,9 c	85.5 ± 2,9 a

*mg tartaric acid/100 mL juice, **mg malvidin 3-glucoside/100g grape skin, ***absorbance values. The values correspond to mean ± SD obtained from three repetions.
Different letters on the same line represent statistically significant differences ($p<0.05$) according to the Tukey Test.

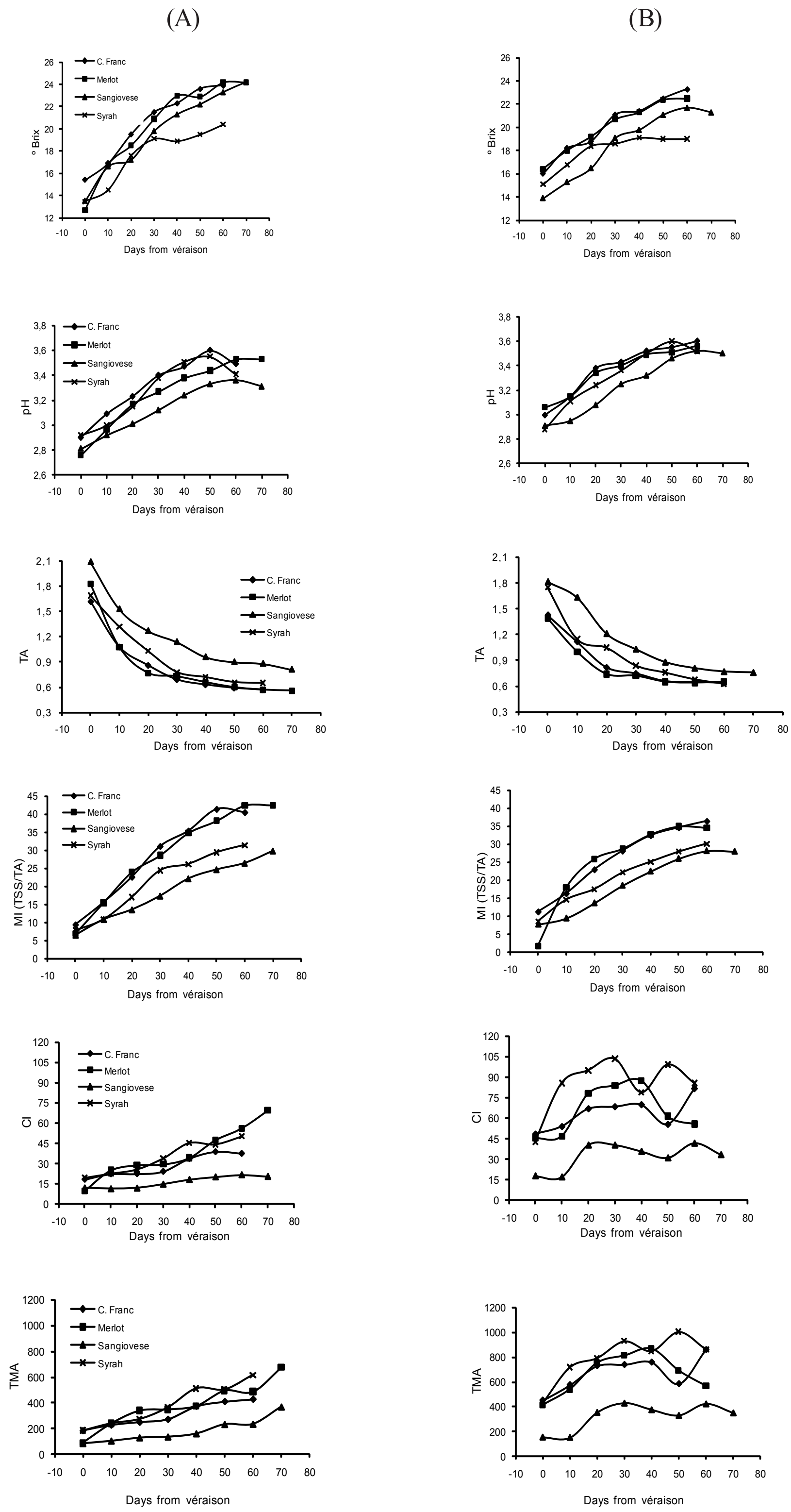

Figure 4. Total soluble solids (TSS - ºBrix), titratable acidity (TA – mg tartaric acid/100mL juice), pH, maturation index (MI = TSS/TA), total polyphenols index (TPI), total monomeric anthocyanins (TMA – mg malvidin 3-glucoside/100g grape skin) and color index (CI) evolution from véraison to harvest for Cabernet Franc, Merlot, Sangiovese and Syrah grapes, for 2006 (A) and 2007 (B) vintages.

As can be seen in Figure 4, the total acidity (TA) decreased during maturation. The different varieties showed different TA values for the two vintages. However, there was no significant difference between the vintages for the variety Cabernet Franc and Syrah. The Sangiovese showed significant differences to the others (p= 0.007), the values being higher (Table 3). All the values observed are suitable for the production of quality wine (less than 1.0 mg tartaric acid 100 mL^{-1} of juice). Similar values are reported by Falcão et al. (2008b) in Cabernet Sauvignon grapes cultived in Santa Catarina State, Brazil.

The pH values during the ripening are shown for the different varieties (Figure 4) and were consistent to the aforementioned TA values evolution. The pH values for the 2006 vintage at the end of the ripening were lower than for the 2007 vintage (p= 0.008). Significant differences were observed between Sangiovese and the others samples for the 2006 vintage. According to Rizzon and Miele (2003) pH values below 3.30 can be negative in terms of the quality of the wine. Amerine and Ough (1976) reported that pH values above 3.60 also negatively affect the quality of wine. The pH of the varieties evaluated in our (this) study were in the range recommended for quality wine (3.30 - 3.60) (Table 3).

The maturity index (MI) is the ratio between the TSS (º Brix) and TA (mg tartaric acid 100 mL^{-1} juice), which represents a balance between sugar and acid, conferring a taste equilibrium to the wine, important to the general quality (Mota *et al*., 2006). Figure 4 shows that the MI values of the grapes for the 2006 vintage were higher than those for the other vintage. Sangiovese and Syrah showed significant differences (p= 0.003) compared with the other varieties. For all varieties the MI was satisfactory, indicating a good maturity of the grapes. According to Gallander (1983), Rizzon and Miele (2003) and Falcão *et al.* (2008b) MI values between 30 and 32 are appropriate for wine production. Riu-Aumatell *et al.* (2002) evaluated the MI of Merlot, Sangiovese and Syrah grapes and found the values to be above 43, which they considered to be satisfactory.

Anthocyanins and others polyphenols are important compounds for the production of quality wine, and they are responsible for wine characteristics such as color, flavor and astringency. Their levels are variable and oscillate according to the climatic conditions (Mateus et al. 2002; Falcão et al, 2008b). The evolution of TMA, TPI and CI values during the maturity of the grapes are shown in Figure 4 for the 2006 (A) and 2007 (B) vintages. Similar behaviors were observed for these phenolics compounds during the ripening. This correlation between phenolic compounds was confirmed by the regression analysis (Figure 5), and demonstrated that TMA, TPI and CI values are strongly correlated among themselves. According to Mazza *et al.* (1999) this is because the anthocyanins directly influence the polyphenol concentration and color intensity, they are the main polyphenols present

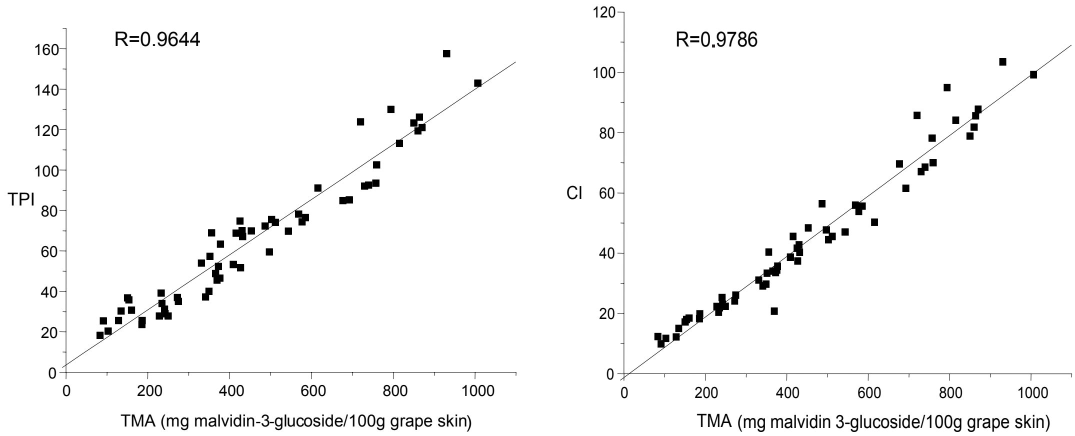

Figure 5. Correspondence between TMA, TPI and CI values during grape ripening for the four varieties evaluated, for 2006 and 2007 vintages. TMA = total monomeric anthocyanins totais, TPI= total polyphenol index, CI= color index.

in the grape skin and are responsible for their red color.

During the ripening period the TMA, TPI and CI values showed an increasing for the 2006 vintage and oscillated during of the 2007 vintage. This is probably due the higher precipitation recorded for this vintage. The precipitation is an important climatic factor in terms of the formation of phenolic compounds in the skin of the grapes (Jones and Davies, 2000). For the 2007 vintage, in general, the anthocyanin content of the grapes increased during ripening but the concentration decreased a few days before harvest.

The differences observed at the end of ripening probably occur due to the different climatic conditions. Significant differences in the phenolic content of grapes from different vintages have been reported (Mazza *et al.*, 1999; González-Neves et al., 2004; Rizzon and Miele 2001) since variations in the climatic parameters, such as radiation, pluviometric index and temperature, influence the anthocyanin synthesis (González-Neves *et al.*, 2007).

Significant differences among the four varieties analyzed were observed in relation to the TMA, TPI and CI values which have been reported by many researches (Mazza *et al.*, 1999; Serrano-Megías *et al.*, 2005; Orak, 2006; Ortega-Regules *et al.*, 2007; Pérez-Lamela *et al.*, 2007). This occurs because, although the environmental conditions under which the grapes were grown have a great influence on the synthesis of polyphenolic compounds, the nature and the different percentages of these compounds follow the determinant genetics of each cultivar (Calò *et al.*, 1996).

The TMA, TPI and CI values observed in our study are consistent with or higher than the results reported by other researchers (Mazza *et al.*, 1999; González-Neves *et al.*, 2004; González-Neves *et al.*, 2007; Romani *et al.*, 1996). This shows a good phenolic ripening, confirming the adaptation of these varieties to the cultivation location, and reflecting good interaction between the cultivars, the climatic conditions and the geographic region. Mateus *et al.* (2002) reported that the climatic conditions observed at the higher vineyard sites appeared to be advantageous, resulting in a greater accumulation of anthocyanins in the grape skin. According to Rosier (2006) on comparing the viticultural regions in Brazil, in regions of higher altitude and lower latitude (28º), such as São Joaquim-SC, the harvest, which is normally carried out in February, occurs in April, a period with low a pluviometric index and classified as 'cold nights' (9.8 ºC). This results in a satisfactory ripening of the grape, favoring an increase in the phenolic concentration of the grapes skin and seed. This leads to an increase in the potential of the grapes in terms of coloration and the aromatic characteristics (Brighenti and Tonietto, 2004) because lower temperatures (10 – 15 ºC) during the ripening also positively influence the anthocyanin synthesis (Mazza and Miniati, 1993; Mori *et al.*, 2005). Some authors consider that for some varieties the optimal temperatures for anthocyanin accumulation in grape berries are in the range of 15 - 25 ºC during the day and 10 - 20 ºC at night (Mori *et al.*, 2005; Kliewer, 1970), which was also verified in our study. Many authors have reported that polyphenol composition is due not only to the type of cultivar but also to the location where the grapes are grown and environmental and management practices, as well as the growing season (Mateus *et al.*, 2002; Jackson and Lombard, 1993; Jones and Davies, 2000).

Application of PCA was carried out on data for all varieties (Figure 6). The analysis explained 85.41 and 96.56 % of the data variability for vintages 2006 and 2007, respectively.

The first axis (Factor 1), in both vintages, was strongly positively correlated with the parameters of coloration (TMA, TPI, CI, Abs 420, Abs 520, Abs 620), MI and pH. This same factor axis showed negative correlated with tonality, TA and BW. For the 2006 vintage (Figure 6A) the tonaltity and TPI were positively correlated with the second axis (Factor 2), but the Abs 620, ºBrix and MI parameters were negatively correlated with the same factor axis. For the vintage 2007 (Figure 6B), Second axis (Factor 2) was strongly positive correlated with ºBrix, IM and

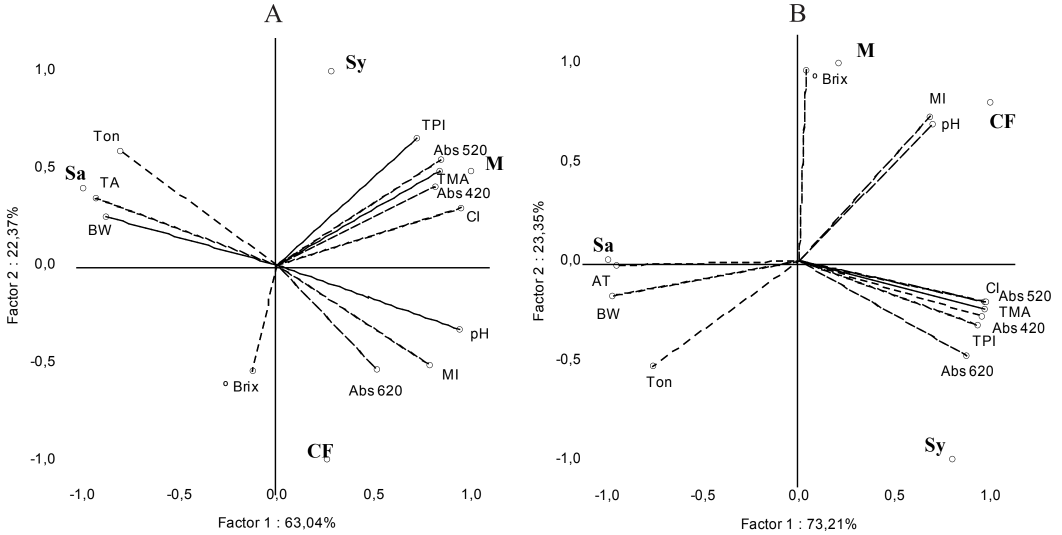

Figure 6. Principal Components Analysis (PCA) of the analysis results of grape at harvest for 2006 (A) and 2007 vintages (B).

pH and negatively with Abs 620 and tonality.
The variable TPI and TMA and the parameters of coloration, CI, Abs 420 and Abs 520 were strongly positively correlated, since the anthocyanins directly influence the polyphenol values and the red grape coloration. Strong positive correlations were also found between the parameters MI and pH, and these parameters showed strong negative correlations with TA, BW and tonality.

The variety Cabernet Franc was associated with the parameters º Brix, MI and pH for the two vintages; for the 2007 vintage these variety also associated with the coloration Abs 620. Merlot variety showed strong association with the TPI, TMA and the coloration parameters in 2006 vintage and for the other vintage were associated with the ºBrix, MI and pH parameters. This shows that these two varieties were probably influenced by climatic differences during the two vintages. For Sangiovese observed association with the TA, BW and tonality parameters, and Syrah variety was associated between TA, TPI and the parameters of coloration for the two vintages.

Conclusions

In general, the results showed that these different grapevine varieties offer satisfactory and typical phenological characteristics during growth and at maturity, in relation to the classical wine growing regions of the world, showing a good adaptation to the cultivation location, São Joaquim-SC. This indicates that Cabernet Franc, Merlot, Sangiovese and Syrah grape varieties show good potential for the production of fine wines, ranking São Joaquim-SC as a suitable region for *Vitis vinifera* grape growing.

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Resumen

E.F. Gris, V.M. Burin, E. Brighenti, H. Vieira y M.T. Bordignon-Luiz. 2010. Fenología y maduración de las variedades de *Vitis vinifera* L. de uva en São Joaquim, sur de Brasil: una nueva región de cultivo de la vid en América del Sur. Cien. Inv. Agr. 37(2): 61-75. Se estudio la fenología y las características de maduración de uvas *Vitis vinifera* Cabernet Franc, Merlot, Sangiovese y Syrah en dos vendimias consecutivas (2006 y 2007), con el fin de evaluar la adaptación de estas variedades cultivadas recientemente en San Joaquim, Santa Catarina (Brasil). Las características fenológicas observadas fueron: brotación, floración, cuajado, envero y vendimia. Se analizaron los niveles de maduración de pH, acidez total, sólidos solubles totales, índice de maduración, el total de antocianos, índice de los polifenoles totales y el índice de color. Los resultados muestran que el ciclo fenológico desde la brotación hasta la vendimia se produjo entre 191 y 219 días y con requerimientos de acumulación de calor de 1.161 y 1.340 grados día. El resumen de los resultados de suma térmica durante el ciclo fenológico de la vid (brotación - cosecha) caracteriza a São Joaquim-SC como “Región I” (<1.389 grados día), es decir, una “zona fría”, en términos de las Regiones Winkler. Los parámetros climáticos influyeron en la fenología de la vid y la maduración de la uva. Los resultados mostraron que estas variedades de uva tenían características típicas en la madurez y que ellos tienen un potencial para la producción de vinos finos, lo que sugiere que San Joaquim-SC es adecuado para el crecimiento de uvas *Vitis vinifera*.

Palabras clave: *Vitis vinifera* L., adaptación, fenologia, maduración, parametros climáticos.

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