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Winter pruning timing, development and quality of Cabernet Sauvignon in Southern Brazil

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Abstract

The objective of this study was to evaluate the influence of winter pruning timing on phenology, productivity, and quality of Cabernet Sauvignon grapes and wines in 2022/2023 production cycle. The experimental design was randomized blocks, with 3 replications, each experimental unit consisted of 5 plants. The treatments involved four pruning timings (end of May, June, July and August). Phenology assessments were beginning and end of bud break, flowering, maturation and percentage of bud break. Production was evaluated by the number of clusters per plant, weight and size of clusters, productivity per plant and per hectare. The analyzes of must were pH, total acidity and soluble solids (°Brix). In wine, pH, total acidity, sugars, alcohol, volatile acidity and color were analyzed. In the end a wine sensory analysis was carried out. The results showed that the bud break of plants pruned early, in May, occurred at the same time as plants pruned in June and July. Early pruning resulted in lower productivity. The grape must from plants pruned late, in August, showed higher total acidity and lower values of soluble solids and sugars. Early pruning did not change the duration of the cultivar's phenological subperiods, nor did it bring forward the harvest in relation to the control. The different pruning times influenced productivity more than the composition of grapes and wines, indicating that it is possible to extend the pruning period.

Keywords: management, phenology, productivity, viticulture, *Vitis vinifera L.*

Introduction

The vine (*Vitis vinifera* L.) is an economically important fruit species in Brazil and in several regions of the world (Fogaça et al., 2022). In the southern Brazil, viticulture has become an important economic and social activity, given the growing increase in wine consumption in the national market (Radünz et al., 2015a).

The vine is a temperate climate plant, which goes through a period of dormancy during autumn and winter, resulting in a temporary suspension of growth of all plant structures (Lamela et al., 2020). Pruning, when carried out on plant shoots during the rest period, is called winter pruning (Maciel et al., 2017).

The timing in which winter pruning is carried out allows the grower to interfere in the relationship between plant development and weather conditions throughout the crop cycle (Radünz et al., 2015a). Pruning influences grape production and quality, and its adequate establishment is based on a good ratio between fruit size, yield and quality (Radünz et al., 2015a; Bueno et al., 2017).

But pruning, like all vine cultivation, requires specialized labor to develop certain essential practices for the crop (Würz et al., 2017). Vines pruning is limited by the logistical difficulties of carrying out all operations in a short space of time, especially in vineyards considered to be large (Buesa et al., 2021).

With the difficulty of carrying out winter pruning, an alternative would be to extend the period of pruning, thus staggering the labor force, either early or late (Souza; Bender, 2022). When pruning is carried out, the vine's phenological cycle begins, influenced by local climate conditions (Abreu et al., 2017). For Abreu et al. (2016), the advancement or delay of vine phenology, caused by different pruning timings, can allow the scheduling of activities in the field.

Tesser and Pauletti (2020) found that the varieties

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Isabel and Cabernet Sauvignon, in Serra Gaúcha, when pruned in April and May, did not show early bud break, but delayed bud break compared to the traditional time (July). In studies carried out by Maciel et al. (2017), with Cabernet Sauvignon in the region of Campanha Gaúcha, early pruning (May) extended the dormancy period, but bud break did not occur at the same time as plants pruned at the usual time.

In this sense, the objective of this study was to evaluate the effect of different timings of winter pruning on the development of Cabernet Sauvignon, considering productive and qualitative aspects.

Material and Methods

The experiment was conducted in commercial vineyards belonging to the company Rigo Vinhedos e Olivais, located in Dom Pedrito, in the 2022/2023 cycle. The vineyard is located at latitude 31°08'46.7" south, and longitude 54°11'53.8" west, at an altitude of 378 meters above sea level. The local soil is a typical to moderate Dystrophic Red-Yellow Argisol with a sandy loam/clay texture, of medium to high depth (Flores et al., 2017; Streck, 2018).

According to INMET climatological standards, the average annual precipitation is approximately 1,400 mm and the average and minimum annual temperature is 18 °C and 14 °C, respectively. The vineyard has a northeast-southwest sun exposure, with spacing of 3.30 m between rows and 1.20 m between plants (2,525 plants per hectare), trained in VSP.

Plants of the Cabernet Sauvignon (clone 169 on rootstock 101-14 Mgt) were evaluated. The experimental design was in randomized blocks, with four treatments (four timings of winter pruning), and three replications (with five plants), totaling 60 plants. Winter pruning was carried out according to criteria already used in the winery, with double spur cordon type and two buds per spur.

The first pruning was carried out in May, 33 days before the winter solstice (05/19/2022) (T1); the second pruning was carried out in June, two days after the winter solstice (06/23/2022), (T2); the third pruning was carried out in July, 33 days after the solstice (07/24/2022) (T3); and the fourth pruning was carried out in August, 63 days after the solstice (08/23/2022) (T4). June is the pruning timing adopted in the winery, and it was therefore considered as the control (T2).

To determine the duration of the phenological stages (days), the count of days required for each stage was adopted, starting from the date of the winter solstice (June 21, 2022). The counting of accumulated Chilling Hours (below 7.2°C) was carried out according to the methodology proposed by Weinberger (1950), as an index of chilling hours necessary to overcome bud dormancy. The calculation was made based on INMET meteorological stations (Bagé/RS - closest station), considering the temperatures at the end of May, date of the first pruning and beginning of leaf fall, until bud break.

The phenological stages were evaluated, using the following parameters: beginning of bud break (BB) and end of bud break (EB), considering the phenological stages of green tip and 5/6 separate leaves, respectively; beginning of flowering (BF) with the first flowers open and end of flowering (EF) with 80% of flowers open; beginning of maturation, phenological stage 35 (BM) and end of maturation and harvest (EM), based on the phenological scale proposed by Eichorn and Lorenz (1984). The percentage (%) of bud break was also evaluated (ratio between the number of sprouted buds and the total number of buds per plant). The duration of the phenological cycle (days) was considered from bud break to the end of maturation (harvest date).

Production data were evaluated by the average number of clusters per plant, productivity per plant (kg), cluster size (cm), cluster weight (g) and estimated productivity (Ton per hectare), calculated based on the production per plant multiplied by planting density. For the average number of clusters per plant, clusters were counted from each repetition of the respective treatment. For the average cluster weight (g), ten cluster from each plot were weighed. The cluster size was measured with a ruler (width and length) of ten randomly selected clusters.

The grapes were harvested at oenological maturity, a time when the main compounds in the grape are in the most favorable concentration for winemaking. In this case, grapes were destined to produce young dry red wine (standards established by the winery). The harvest was carried out manually. The clusters were packed in boxes (capacity of 20 kg), separated by treatment. After harvesting, the grapes were transported to the Federal University of Pampa (Dom Pedrito). They were then acclimatized in a cold chamber (4°C), for vinification in the following day.

After weighing, the grapes were de-stemmed and crushed, when samples were collected (50ml Falcon tubes) for must analysis, carried out by infrared spectroscopy with the Wine Scan equipment (Wine Scan™ SO2, Foss®, Denmark) and software Foss integrator version 1.6.0. Soluble solids were expressed in °Brix (SS), Hydrogen potential (pH), Reducing sugars (g L^{-1}) and Total Acidity (mEq L^{-1}) were then measured.

In the must, obtained after de-stemming and crushing, SO_2 (Potassium Metabisulfite) was added at a dose of 100 mg L^{-1}, considering the sanitary quality of the grapes. After 30 minutes, the enzyme Colorpect VRC® was applied to the must, at a dose of 2 g hl^{-1}. The red grape must fermented with the skins, using *Saccharomyces cerevisiae* AWRI 796® yeast (25 g hl^{-1}) and 25 g hl^{-1} of the nutrient Gesferm®.

Fermentation was monitored daily with density and temperature measurements (21°C to 24°C), lasting seven days. After the end of wine fermentation, the grapes were pressed using a manual press, and the wines remained at a temperature close to 24°C so that malolactic fermentation could begin. After malolactic fermentation, the wines were taken to the cold room for tartar stabilization, at a constant temperature of 4°C. After this stage, the wines had the SO_2 corrected and were bottled.

The wines were analyzed by infrared spectroscopy using Wine Scan equipment (Wine Scan™ SO2, Foss®, Denmark) and Foss integrator version 1.6.0 software. The pH (Hydrogen potential), total acidity (mEq L^{-1}), volatile acidity (mEq L^{-1}), alcohol (% v/v); reducing sugars (g L^{-1}) were measured. The wine color at absorbances 420nm, 520nm and 620nm was also determined and the color intensity (I = 420 nm + 520 nm + 620 nm) and color tone (T = 420 nm / 520 nm) were determined.

The wines were subjected to quantitative descriptive analysis, consisting of a panel of ten previously trained tasters. The descriptive sheets developed by OIV and adapted for the study were used. The evaluators established grades that varied between excellent and insufficient using a structured scale. In the visual component, the following were evaluated: color intensity, clarity and general appearance. In the olfactory component, the following were evaluated: intensity, sharpness, defects and general quality. For taste characteristics, the following were evaluated: acidity, astringency, body, balance, persistence, unctuousness/ creaminess, undesirable taste and general quality. At the end, a score was assigned for the overall appearance of the evaluated sample.

The results were submitted to the statistical parameters of Anova, using the t test and Tukey test with 0.05 (5%) probability of error, using the statistical software Sisvar ® Version 5.6 (1996).

Results and Discussion

Plants pruned in May remained dormant for longer but sprouted at the same time as plants pruned in June and July (**Table 1**). When pruning early (in autumn or early winter), the roots are dormant (as are the aerial parts) and, even after cutting the shoots, sprouting does not occur due to the lower soil temperature (Santos; Silva, 2016).

Studies carried out by Maciel et al. (2017), evaluating the different pruning timing in Cabernet Sauvignon, reported that plants pruned in June began fruiting nine days before plants pruned in May and July, but began maturation in the same period. A similar result was observed in this study, as the maturation period was similar for the different pruning timings. In turn, fruiting varied by three days between treatments.

A delay of nine days was observed in the beginning of bud break for plants pruned in August. Maciel et al. (2016), when evaluating different pruning timing in the Campanha Region, observed that late pruning (end of August) delayed the beginning of bud break of Cabernet Sauvignon.

The shortest total cycle (188 days) was observed for plants pruned in August. The total cycle was greater when compared to the results found by Radünz et al. (2015b), with an average of 174 days for Cabernet Sauvignon. In research carried out by Perin et al. (2023), with Syrah and Malbec, they concluded that the seasonal patterns of phenological development, in late pruning and regular pruning trials, restarted the phenological process at a similar pace, with a difference of one week between late pruning and the other timings. However, all treatments, after the start of maturation, followed similar phenological stages, a similar behavior was found for Cabernet Sauvignon in this work.

The same number of chilling hours (CH) was required for bud break of plants pruned in May, June and July (328 hours); 356 chilling hours were required for plants pruned in August. The higher requirement for chilling hours of plants pruned in August may be related to a longer period of dormancy. Even so, the accumulated chilling hours were sufficient for uniform bud break, in all timings of winter pruning. Normally, around 400 chilling hours are needed to overcome the endodormancy of 'Cabernet Sauvignon' buds, under a constant thermal regime of 7.2°C (Fogaça et al., 2022).

The results of production and productivity assessments are presented in **Table 2**. There were no differences between pruning timing for cluster weight, length and width. However, plants pruned in August presented a greater number of clusters compared to plants pruned in May. Plants subjected to late pruning (August) expressed the highest productivity (3.4 kg per plant and 8,780 kg per hectare). The lowest values for

Table 1. Number of days necessary for the occurrence of phenological stages, days for the solstice, chilling hours and bud break for the different pruning timings.

Pruning Timing	Days for solstice	BB(BB-EB)	EB(EB-BF)	BF(BF-EF)	EF(EF-BM)	BM(BM-EM)	EM(Total)	Chillinghours	Bud break(%)
May	-33	62 a (12b)	74 a (58c)	132 b (8a)	140 ab (63b)	203 b (55a)	258 a (196b)	328	92%
June*	-8	62 a (12b)	74 a (57b)	131 a (8a)	139 a (64c)	203 b (55a)	258 a (196b)	328	93%
July	33	62 a (12b)	74 a (57b)	131 a (8a)	139 a (63b)	202 a (56a)	258 a (196b)	328	94%
August	63	72 b (6a)	77 b (56a)	133 c (9b)	142 b (62a)	204 c (55a)	259 b (188b)	356	88%
	CV (%)	0.63 (1.37)	0.54 (0.25)	0.22 (1.74)	0.65 (0.23)	0.20 (3.12)	0.11 (0.26)		

* Control. BB: beginning of bud break; EB: end of bud break; BF: beginning of flowering; EF: end of flowering; BM: beginning of maturation; EM: end of maturation. Different letters in the columns express significant statistical differences by Tukey Test (p < 0,05).

Table 2. Average productivity assessments and physical-chemical analysis of Cabernet Sauvignon pruned at different timings.

Pruning Timing	Cluster Weight (g)	Clusterper Plant	Cluster Length(cm)	Cluster Width(cm)	Prod. (Kg)	Estimated Prod. (Kg per ha)	Residualsugar (g L^{-1})	SS° Brix	TA(meq L^{-1})	pH
May	109.3 a	20.1 a	13,4 a	7,4 a	2.2 a	5537 a	229.9 b	22.5 b	77.3 b	3.52 c
June*	138.5 a	20.8 ab	14.0 a	8.6 a	2.9 b	7274 b	239.6 d	23.3d	74.7 a	3.54 d
July	133.6 a	20.5 ab	15.0 a	8.7 a	2.7 b	6929 b	235.4 c	23.9 c	78.2 c	3.51 b
August	149.2 a	23.3 b	15.4 a	8.7 a	3.5 c	8790 c	227.8 a	22.4 a	86.7 d	3.45 a
CV (%)	48.57	20.75	24.68	25.85	9.98	9.98	0.25	0.13	0.48	0.05

* Control. Different letters in the columns express significant statistical differences by Tukey Test (p < 0.05). TA: Total Acidity. Prod: Productivity.

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productivity were observed in plants subjected to early pruning (May). Pruning, carried out during an incomplete period of senescence, combined with a longer period between pruning and bud break, may have influenced a lower accumulation of metabolites, reducing plant productivity. Maciel et al. (2017), observed that late pruning (August) of Cabernet Sauvignon resulted in higher productivity, when compared to pruning carried out at the usual time (June to July).

Table 2 also describes the results of must analyses. Reducing sugars and soluble solids showed higher concentrations when plants were pruned in June and July, respectively. In relation to total acidity, the highest values occurred when plants were pruned in August. The pH of the musts was higher when plants were pruned in June and lower when plants were pruned in August. The duration of phenological periods and, mainly, the climatic factors during maturation, may have influenced the composition of the grapes. Temperature is one of the most important factors in sugar accumulation in berries (Gutiérrez-Gamboa et al., 2021).

Plants pruned in August produced grapes that presented higher levels of total acidity and lower levels of soluble solids and reducing sugars. These results were influenced by the shorter duration of phenological cycles, defined by late pruning. For Netzer et al. (2022), late pruning was not effective in delaying the harvest, however, it delayed the accumulation of sugar and the degradation of total acidity in Malbec grapes. Buesa et al. (2021), evaluating Bobal and Tempranillo, observed that berry ripening was significantly affected by the pruning timing, increasing the total acidity of the must, compared to early pruning. For Petrie et al. (2017), pH and soluble solids values were higher the later the vines were pruned, differently from the results observed in this study.

Table 3 presents the results of wine physicochemical analyzes. Reducing sugars confirmed the classification of the wines as dry, with residual sugar below 4 g L^{-1}, as established by Brazilian legislation (Law 7,678/1988).

For volatile acidity, all treatments showed high concentrations. This high volatile acidity may be the result of microbiological changes during winemaking, or higher pH values. Lower pH levels (acids), close to 3.3, help preserve wines, avoiding microbiological contamination, such as acetic bacteria, which are the main promoters of acetic acid, the majority component of volatile acidity. However, volatile acidity remained within the parameters required by Brazilian legislation, below 20 meq L^{-1} (IN 14/2018). In wines with concentrations close to 15 meq L^{-1}, volatile acidity can be noticeable, with aromas of acetic or vinegary odor. The pH was highest in wines originated from grapes of plants pruned in June and lowest for plants pruned in August.

The lowest alcohol concentrations were observed when plants were pruned in August, following the same premise as for soluble solids and residual sugar (must). In this treatment, a shorter phenological cycle, due to late pruning, influenced the lower sugar accumulation in the grapes, reflecting the alcohol content. The wines showed higher acidity values when plants were pruned in July. However, the acidity of the musts (Table 2) was lower than the acidity of the red wines.

This fact may be correlated to the fruit composition in relation to organic acids and the berry size, which determines a different proportion between the skin and the pulp, in addition to the acidity of berry skin. The increase in total acidity was observed after fermentation of Isabel grapes, due to the release of organic acids from the skin, characteristic of the vinification of this grape (Rizzon; Miele, 2006).

The parameters that express the wine color showed differences between the treatments. A420 presented higher values when plants were prune in May and June (0.759 and 0.757), the same dynamics observed for A520 and A620. When measuring optical densities, A520 and A420 nm express the colors purple and yellow, respectively, while A620 nm expresses the blue color of young wines (Ribereau-Gayon et al., 2006). The color tone did not show significant differences between pruning timings and corresponds to the evolution of the wine's color to orange. In young wines, they vary between 0.5 and 0.7. Color intensity showed a significant difference between treatments. It normally varies between 0.3 and 1.8, depending on the cultivars and wine types (Ribereau-Gayon et al., 2006). Similar results were found by Moran et al. (2018), observing that late pruning in Shiraz did not affect the color tone of the wine, unlike the color intensity, which was more intense in wines originating from late pruning.

Regarding the results obtained for the wine sensory analysis, in the visual aspects (**Figure 1**) it was possible to observe that the predominant color recognized by the evaluators was ruby red, similar for all treatments. This color is characteristic of young red wines of Cabernet Sauvignon.

Plants pruned in June (Control) presented the best overall olfactory quality. For plants pruned in May

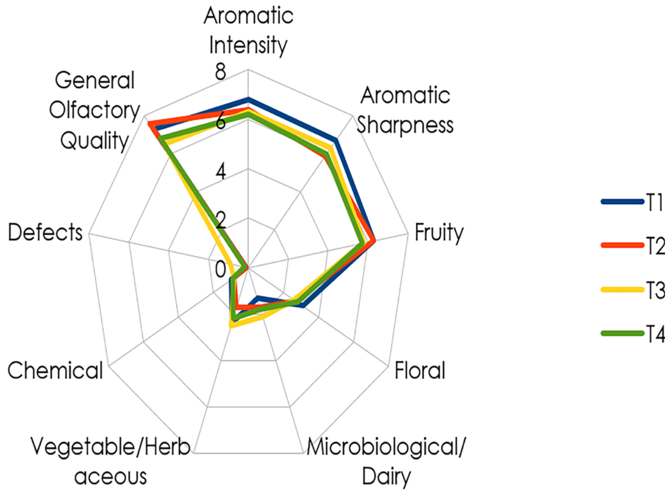

Figure 1. Olfactory aspects of Cabernet Sauvignon wines produced from vines with different pruning timings. May: T1, vine pruning 33 days before the winter solstice; June (Control): T2, vine pruning two days after the winter solstice; July: T3, vine pruning 33 days after the solstice; August: T4, 63 days after the winter solstice.

and July, the evaluators described fermentative and dairy aromas, reminiscent of yogurt. The wines presented predominant aromas of red fruits (cherry, strawberry, blackberry and raspberry), spices (clove), ripe black fruits (plum), floral (violet, roses), tobacco, chocolate and coffee.

The aroma of a wine is one of the main factors that determine its nature and quality, especially its organoleptic characteristics, playing a crucial role in consumer preference (Jiang et al., 2013). Some aromatic compounds are released directly from grapes, while others form during the fermentation and aging process (Jiang et al., 2013).

In **Figure 2** it is possible to observe the main gustative aspects of the wines evaluated. The wine originated from plants pruned in June (Control) was the one that obtained the most expressive evaluation in relation to general taste quality, balance and body.

In studies conducted by Miele and Rizzon (2019), with the Cabernet Sauvignon variety, the authors also found wines with a general quality close to a rating of 'eight' and aromatic intensity around 'seven'.

Perceptions of flavor, color, aroma and mouthfeel occur through complex chemical reactions involving acids, phenolic compounds (such as tannins) and sugars in a wine, as well as changes in these perceptions (Silva et al., 2018).

The overall assessment (**Figure 3**) followed this same premise for the control, which presented the best evaluation. Wines from plants subjected to late pruning also stood out in terms of general taste quality and global assessment.

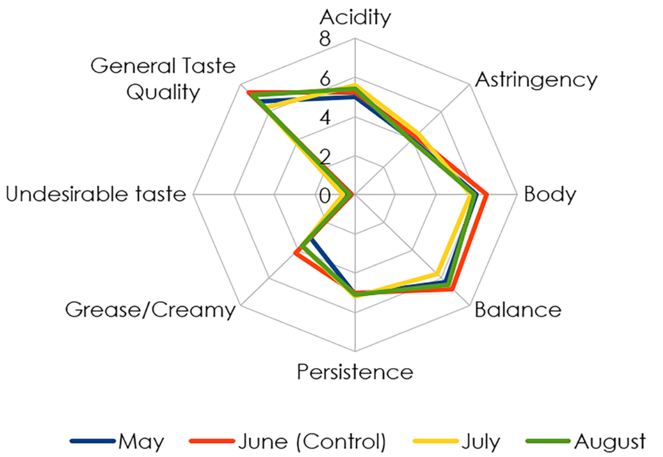

Figure 2. Gustative aspects of Cabernet Sauvignon wines produced from vines with different pruning timings. May: T1, vine pruning 33 days before the winter solstice; June (Control): T2, vine pruning two days after the winter solstice; July: T3, vine pruning 33 days after the solstice; August: T4, 63 days after the winter solstice.

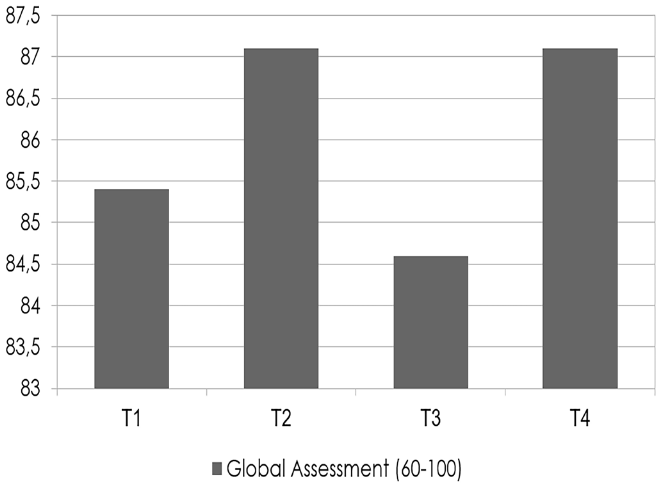

Figure 3. Overall assessment of Cabernet Sauvignon wines produced from vines with different pruning timings. May: T1, vine pruning 33 days before the winter solstice; June (Control): T2, vine pruning two days after the winter solstice; July: T3, vine pruning 33 days after the solstice; August: T4, 63 days after the winter solstice.

According to Caliari and Zanus (2019), wines from Cabernet Sauvignon are red, with aromas of black fruits (plum, blackberry), tobacco, coffee, spices, in the taste, present and pleasant tannins, medium acidity, complex and full-bodied. This description corroborates what was found in this study for the wines evaluated.

The characteristics, typicality and quality of the wine depend mainly on the genetics of the vine, the environment, the cultural practices used in the vineyard and the oenological processes during winemaking (Rizzon; Miele, 2017).

Conclusions

Early pruning did not change the duration of the sub-periods, nor did it bring forward the harvest. Late pruning decreased and reduced bud break, in addition reduced the duration of phenological stages, without bringing forward the harvest.

Early pruning decreased production, while late pruning increased production.

The quality of the grapes and wines were not negatively influenced by the different pruning timings.

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