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Pruning times on the phenology and quality of chardonnay vine (*Vitis vinifera L.*)

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Abstract

The pruning time can influence the performance of the vine, depending on the local conditions in which it is located. The present study aimed to evaluate the influence of pruning times on the phenology of the Chardonnay vine, on the productivity and quality of the grape and wine in the 2022/2023 production cycle. The experimental design was in randomized blocks, with 3 replications and an experimental unit of 5 plants. The treatments consisted of four pruning times (at the end of May, June, July and August), with assessments of phenology (at the beginning and end of budding, flowering, and maturation), percentage of bud sprouting, production and quality of grapes and wine. Production was evaluated in number of bunches; average weight and size of bunches; productivity per plant and per hectare. The analyzes of must before processing, and wine, were pH; total acidity; sugars, alcohol and volatile acidity. Early pruning (T1) reduces the duration of phenological cycles. Early pruning resulted in lower production. The must from control (3) presented the highest value for total acidity. T1 did not change the duration of the phenological subperiods nor did it bring forward the harvest, in relation to the control. However, it may increase the risk of damage to shoots due to late frosts, in years with winter temperatures close to 0 °C. The different pruning times influenced the productivity and not the composition of the grapes. It is possible to extend the pruning period and stagger the workforce to carry out dry pruning.

Keywords: harvest, grape, management, viticulture, wine

Introduction

Viticulture plays a significant economic role in Brazil, especially in traditionally wine-producing regions. Its importance has grown over the last few years, due to factors such as national and international recognition of the quality of the wines produced, regional development fostered by job and income generation, and the growth of wine tourism and associated economic chains (Miranda, 2020).

The Campanha Gaúcha, the second largest fine wine-producing region in Brazil, accounts for more than 30% of the country's production (Stein et al., 2018). Its conditions have been favorable for the production of quality wines, due to the sandy and drained soils, high levels of solar radiation, and low rainfall during the ripening period (Costa et al., 2019; Aloy et al., 2024).

Chardonnay (Vitis vinifera L.), among the white varieties, is one of the most produced and used varieties for wine production. It is considered versatile and widespread due to its ability to adapt to different climates and soils.

Grape quality depends on the phenology of the vine, and is directly related to the characteristics of the cultivar and the management practices applied during the production cycle (Maciel et al., 2020).

Pruning is one of the most prominent management practices. It involves the removal of shoots, branches, and leaves, aiming to influence the development of the vine and optimize production (Vanderweide et al., 2021). Choosing the time and intensity of pruning are essential to achieve the quality and quantity of grapes produced (Allebrandt et al., 2017; Leão et al., 2018; Lamela et al., 2020).

Winter pruning consists of eliminating part of the plant branches during the dormant period of the vines (Maciel et al., 2017), usually performed at the end of

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winter. Pruning requires knowledge and experience (Würz et al., 2017) and, as it is a time-consuming practice that must be carried out in a short space of time (Buesa et al., 2021), it is often carried out outside the recommended season. Thus, an alternative would be to extend the dry pruning period, staggering the labor force (Souza & Bender, 2022). In a study carried out with the Sauvignon Blanc variety in Dom Pedrito, RS, Brazil, evaluating different pruning times, Aloy et al. (2024) observed that different pruning times did not influence the phenological stages of the plants, allowing the producer to start winter pruning in the vineyard before the usual pruning season, or extend the pruning for a longer period. Therefore, it is possible to extend the dry pruning period, staggering and optimizing the labor force in the vineyards. The aim of this study was to evaluate the effect of different dry pruning times on grape development and wine quality of cv. Chardonnay.

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, with an altitude of 378 meters above sea level. The local soil is a Dystropic Red-Yellow Argisol typical to moderate, with a sandy/clay loam texture, of medium to high depth (Flores et al., 2017; Streck, 2018). The region's climate is classified as humid subtropical, type Cfa (Moreno, 1961). According to INMET data, the average annual rainfall is approximately 1,400 mm and the average and minimum annual temperature is 18 °C and 14 °C. The vineyard has northeast-southwest sun exposure, with plants arranged 3.30 m between rows and 1.20 m between plants (2.525 plants ha^{-1}), conducted in an espalier system.

The Chardonnay variety (clone 809 on SO4 rootstock) was evaluated. The experimental design was in randomized blocks, with four treatments (winter pruning times), and three replications of five plants, totaling 60 plants. Pruning was carried out according to criteria used in the vineyard, of the Guyot type, leaving three branches with seven buds and three spurs with two buds, on each plant (totaling 27 buds per plant).

The determination, in days, of the phenological stage of the treatments (T) was carried out from the date of the winter solstice (June 21, 2022). The first pruning was carried out in May, 33 days before the winter solstice (T1); the second in June, two days after the winter solstice (T2); the third in July, 33 days after the solstice (T3); and the fourth in August, 63 days after the solstice (T4), all in the 2022 year. July is the pruning time used in this vineyard, and this month is considered as a control.

The phenological stages were evaluated, observing the beginning of budding (BB) and the end of budding (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 (EM), based on the phenological scale proposed by Eichorn and Lorenz (1984). The percentage of sprouting was evaluated (ratio between number of shoots and total buds per plant). The length of the phenological cycle (days) started from the date of sprouting until the end of maturation (harvest date).

The counting of accumulated Cold Hours (CH) (below 7.2 °C) was performed according to the methodology proposed by Weinberger (1950), as an index of "cold hours" necessary to overcome dormancy in fruit buds. The calculation was made based on the meteorological stations of INMET (Bagé/RS - closest station to the site), considering the temperatures at the end of May, the date of the first pruning and the beginning of leaf fall, until budding.

The production data were evaluated by the average number of bunches per plant, yield per plant (kg), bunch size (cm), average bunch weight (g) and estimated yield (ha), calculated based on the yield per plant. For the average number of $plant^{-1}$ bunches, the bunches of five plants (each replicate) of the respective treatment were counted. For the average bunch weight (g), the weight of 10 bunches of each treatment was measured after harvest. The size of the bunches was measured with a ruler (width and length) of 10 randomly selected bunches.

The grapes were harvested at oenological maturity, when the main compounds in the grape are at the most favorable concentration for obtaining wine. The harvest was carried out manually, randomly. The bunches were placed in boxes (20 kg capacity), separated by treatment. After harvest, the grapes were transported to the Federal University of Pampa (Campus Dom Pedrito), where they were stored in a cold room (4 °C) for a 24 hours.

After weighing, the grapes were destemmed and crushed, and samples were collected for analysis of the must, which were carried out using infrared spectroscopy on the Wine Scan equipment (Wine Scan™ SO_2, Foss®, Denmark) and Foss integrator software version 1.6.0. Analyzes of soluble solids expressed in °Brix (SS), pH, reducing sugars (g L^{-1}) and Total Titratable Acidity (mEq L^{-1}) were carried out. After stalking and crushing, 100 mg L^{-1} SO_2 (Potassium Metabisulfite) was added to the must, considering the sanitary quality of the grapes.

To improve liquid extraction and increase yield, the liquid enzyme Coavin MXT® (5 mL hl^{-1}) was applied, which also favors the release of aromas and helps clarify the must. After another 30 minutes, the pressing of the grapes began using a manual press. The must obtained was placed in glass bottles (14 L). Vinifications occurred in triplicate, for each treatment. The clarifiers used to help pre-clean the must were Solisil 30® Silica (60 g hl^{-1}), after 15 minutes PVPP (10 g hl^{-1}) was added and after 1 hour, LikGel® Gelatin (30 g hl^{-1}). The musts remained for 24 hours at a temperature of 4 °C for debourbage.

The yeast used in alcoholic fermentation was the species *Saccharomyces cerevisiae* Tropica® (30 g hl^{-1}) and 10g hl^{-1} of the nutrient Nutrimax®. Fermentation was monitored daily with density and temperature measurements, maintained between 18 °C and 19 °C, during 12 days. At the end of wine fermentation, 50 mg L^{-1} of Potassium Metabisulfite (SO_2) was added to avoid malolactic fermentation.

Protein stabilization was carried out using previously hydrated Bentonite (g hl^{-1}), PVPP (20 g hl^{-1}) and Glutathione Glutamax® (20 g hl^{-1}), for seven days at 18 °C. Afterwards, the wines were transferred to glass containers for bottling. The wines were analyzed by infrared spectroscopy using Wine Scan equipment (Wine Scan™ SO2, Foss®, Denmark) and Foss integrator version 1.6.0 software: pH, Total Titratable Acidity (mEq L^{-1}), Volatile Acidity (mEq L^{-1}), Alcohol (% v/v) and Reducing sugars (g L^{-1}).

Sensory analysis was conducted using a panel of ten previously trained judges. Quantitative descriptive profile sheets, with a 9-point scale, were prepared for the study. In the visual assessment, color intensity, clarity and general appearance were evaluated. In the olfactory evaluation, intensity, sharpness, defects and general quality were evaluated. For taste characteristics, acidity, astringency, body, balance, persistence, unctuousness/creaminess, undesirable taste and general quality were evaluated. A score was also given for the overall appearance of the sample.

The results obtained were treated using Anova, and the t test with 0.05 (5%) probability, using the statistical software Sisvar® Version 5.6 (1996).

Results and discussion

The plants in T1 remained dormant for longer and began sprouting before the other treatments (**Table 1**). Treatment 4 started sprouting later compared to the other treatments, probably due to late pruning. Both treatments differed statistically from the control (T3). Similar results were observed for the end of Sprouting.

In early pruning (in autumn or early winter), the roots are dormant (as well as the aerial part) and, even after cutting the shoots, sprouting will not occur due to the lower soil temperature (Santos & Silva, 2016 cited by Maciel et al., 2020).

Bud sprouting (%) was lower in T4 (85%). This lower percentage of sprouted buds is related to the proximity (period) of pruning to bud sprouting. This dynamic is directly linked to a physiological factor, called “apical dominance”. The buds in the apical portion of the branches burst first, inhibiting the growth of the basal buds, reducing the percentage of buds sprouted (Petrie et al., 2017). Studies carried out by Bueno et al. (2017) with the Cabernet Sauvignon cultivar, found a lower percentage of bud sprouting in plants pruned in mid-August.

The total cycle for the cultivar varied between 189 (T1) and 178 days (T4). The cycle was longer when compared to the result found by Radünz et al. (2015), with an average of 152 days for Chardonnay. The values for BM were similar, however the duration of the BM-EM period was shorter for T1 compared to T3 (control).

Chardonnay showed less need for chilling hours for the sprouting of plants pruned early (T1), probably because it is an early cultivar. A greater need for cold hours was observed for T4, related to a longer period of dormancy. The accumulated chilling hours were sufficient for uniform sprouting, in all periods of winter pruning. A total of approximately 150 hours of cold are necessary to overcome the endodormancy of Chardonnay buds, under a constant thermal regime of 7.2 °C (Monteiro et al., 2013; cited by Fogaça et al., 2022).

The results of production and productivity assessments are represented in **Table 2**. The weight, size, length and width of the bunches did not differ between treatments. However, the number of bunches per plant was higher for T3 (control).

In relation to productivity per plant, the highest values were found for T3 (more than three kilos per plant), consequently, the estimated productivity per hectare, with more than 8,100 kg. The lowest values for these variables were found for T1, with 2.4 kg per plant and approximately 6,100 kg ha.

Early pruning resulted in decreased production. Pruning, carried out during an incomplete period of senescence, and the longer period between pruning and sprouting, may have influenced a lower accumulation of metabolites, reducing plant productivity.

Table 2 also describes the results of the must analyses. Reducing sugar levels were highest in T1 (252.86 g L^{-1}) and lowest in T4. The lowest total acidity was observed in T1 and T2, not statistically different from T4. The pH did not follow the acidity trend, presenting the lowest concentration (3.42) in T4, and the highest in T2 (3.51).

The genetic factor of the cultivar, the duration of the phenological periods and the climatic factors during maturation may have influenced the composition of the grapes. In this case, the high sugar and pH values, combined with low acidity levels, may have been influenced by climatic factors, beneficial to the maturation of the grapes.

The 2022/2023 harvest was characterized by the phenomenon called La Niña, minimizing rainfall and causing higher temperatures in the Campanha Region. This phenomenon may have contributed to the composition of the grapes, especially the white grapes, modifying the physiology of the vine, especially during the maturation period. Temperature is extremely important in the accumulation of sugar in berries, with the ideal range being between 25 and 35°C (Gutiérrez-Gamboa et al., 2021).

Table 3 presents the results of the physicochemical analyzes of the wines. The reducing sugars confirmed the classification of the wines as dry, (residual sugar below 4 g L^{-1}, as established by Brazilian legislation (Law 7.678/1988), which characterizes the perfect development of alcoholic fermentation. The total acidity for the Chardonnay wine was higher for T1, following the same trends as the must analyses. The lowest pH value was found for T1. The alcohol content, despite showing a difference between treatments, is high for white wines, between 14% and 15. %, attributed to the high accumulation of sugars and solids.

All treatments presented concentrations above 11 mEq L^{-1} of volatile acidity. This high volatile acidity may have been influenced by changes during winemaking, or by higher pH values. Lower pH levels (acids), close to 3.3, help preserve wines, avoiding microbiological contamination, such as acetic bacteria, the main promoters of acetic acid, the majority component of volatile acidity. However, all treatments comply with the limits established by legislation for volatile acidity, up to 20 mEq L^{-1} (Law 7,678/1988).

Table 1. Number of days required for the occurrence of periods (phenological sub-periods), days for the solstice, chilling hours and bud sprouting for the different pruning times

Pruning Time	Days until solstice	BB (BB-EB)	EB (EB-BF)	BF (BF-EF)	EF (EF-BM)	BM (BM-EM)	EM (Full cicle)	CH	Sprouting(gems)
T1	-33	46 a (15b)	55 a (65 c)	120 a (6a)	126 a (62d)	188 a (41a)	235 a (189d)	254	92%
T2	2	51 b (9a)	60 b (62b)	122 b (6a)	128 b (60c)	188 a (47b)	235 a (184b)	279	94%
T3*	33	51 b (9a)	60 b (65c)	125 c (5a)	130 c (59b)	189 b (47b)	236 a (185c)	279	92%
T4	63	59 c (10a)	69 c (58a)	127 d (7b)	134 d (56a)	190 c (47b)	236 a (178ª)	286	85%
	CV (%)	0.56 (5.54)	0.47 (0.65)	0.33 (7.00)	0.45 (0.98)	0.22 (1.1)	2.86 (0.11)		

*Control treatment. Beginning of Budding (BB), End of Budding (EB), Beginning of Flowering (BF), End of Flowering (EF), Beginning of Maturation (BM), End of Maturation (EM), Sprouting gems (%); Cold hours (below 7.2 °C). Coefficient of variation (CV); a'b'c': different letters in the columns express significant statistical differences. Anova statistical parameters, with t-test at 0.05 (5%) probability.

Table 2. Means of productivity assessments and physical-chemical analysis of must from Chardonnay grapes pruned at different times, in Dom Pedrito, RS, Brazil

Pruning Time	Weight(g)	Curls plant^{-1}	W (cm)	L (cm)	Prod. kg plant^{-1}	Prod.kg ha^{-1}	RS (g L^{-1})	SS °Brix	TA (mEq L^{-1})	pH
T1	123.3 a	19.8 a	13.0 a	7.5 a	2.4 a	6166 a	252.9 c	24.3 c	87.5 a	3.46 b
T2	127.1 a	21.1 a	12.8 a	8.2 a	2.7 ab	6784 ab	249.8 b	24.1ab	88.0 a	3.51 c
T3*	130.0 a	24.9 b	11.4 a	7.8 a	3.2 b	8184 b	250.8 b	24.2 b	90.7 b	3.47 b
T4	136.0 a	20.9 a	12.5 a	8.1 a	2.6 a	6658 a	247.9 a	24.0 a	89.3 ab	3.42 a
CV (%)	21.08	16.43	14.87	20.0	11.05	11.05	0.39	0.24	1.37	0.26

*Control treatment, Coefficient of variation (CV), Length (L), Width (W), Production (Prod), Reducing Sugars (RS), Soluble Solids (SS), Total Acidity (TA), Coefficient of variation; a'b'c': different letters in the columns express significant statistical differences. Anova statistical parameters, with t test at 0.05 (5%) probability of error. (T): Witness, producer's usual pruning time. T1: May, 33 days before the winter solstice; T2: June, two days after the winter solstice, July: 33 days after the solstice; T4: August, 63 days after the solstice (T4), all in the 2022 year.

Table 3. Physicochemical analyzes of wine from Chardonnay grapes from the 2023 harvest, pruned at different times, in Dom Pedrito, RS, Brazil

Pruning Time	Alcohol (%v/v)	Total Acidity (mEq L^{-1})	pH	Volatile Acidity (mEq L^{-1})	Reducing Sugars (g L^{-1})
T1	15.2c	81.3b	3.69a	13.33b	0.60ab
T2	15.1b	77.8a	3.78c	13.33b	0.90b
T3*	15.2c	77.3a	3.78c	13.33b	0.46a
T4	15.0a	77.3a	3.71b	11.66a	0.40a
CV (%)	0.19	0.49	0.08	0.10	29.68

*Control treatment. CV: Coefficient of variation; a'b'c'd': different letters in the columns express significant statistical differences. Anova statistical parameters, with t-test at 0.05 (5%) probability. T1: May, 33 days before the winter solstice; T2: June, two days after the winter solstice, July: 33 days after the solstice; T4: August, 63 days after the solstice (T4), all in the 2022 year.

The results of the sensory analysis for the visual, olfactory and gustatory aspects are presented in **Figures 1**, **2** and **3**, respectively.

The predominant color tone for all treatments was straw yellow with golden reflections. The color intensity was more expressive for T2.

The Figure 2 illustrates the results obtained in the different treatments, considering the quality, intensity and aromatic clarity, defects and the groups of aromas identified. Treatment 1 presented greater clarity of aromas and aromatic intensity, while T2 expressed more fruity aromas, and T3 enhanced the perception of floral aromas, which may have contributed to a better overall olfactory quality.

For the olfactory analysis, aroma descriptors such as honey, green apple, fruit in syrup, floral and fruity appeared more evident in T1. Floral, honey, liqueur, fruity (passion fruit, apple, pineapple) were mostly perceived in T2; while aromas of pineapple, passion fruit, floral (roses, white flower), mentholated herbaceous (mint, mint) in T3. In Treatment 4, similar to T3, the evaluators described aromas as floral (white flowers), fruity (pineapple, apple, persimmon), mentholated herbaceous (mint, mint), as well as sweet (honey, caramel).

The perception of aromas was similar for all treatments, however some expressed more intense floral aromas (T2 and T4), fruity aromas (T3) and sweet aromas reminiscent of honey (T1). The wine made with the Chardonnay cultivar is traditionally characterized by having aromas reminiscent of green apple, tropical fruits (pineapple) and ripe citrus fruits (Romagna, 2018).

In Figure 3 it is possible to observe that T1 presented a more pronounced expression for the sensation of unctuousness and creaminess on the palate. Treatment 3 showed greater expression. The treatment 3 showed greater expression for acidity and body, which resulted in the best balance and general taste quality of the wines.

The **Figure 4** expresses the overall evaluation of the wines described by the evaluators, considering described parameters. The best evaluation was for treatment T3, which also presented the best general olfactory quality, body, balance, acidity and general taste quality. Treatment 1 was similar to T3 with an approximate score. The wine with the lowest overall evaluation was T2, which can be attributed to the lowest evaluations for general olfactory and gustatory quality, influenced by the aromatic characteristics and taste quality attributes of the wine.

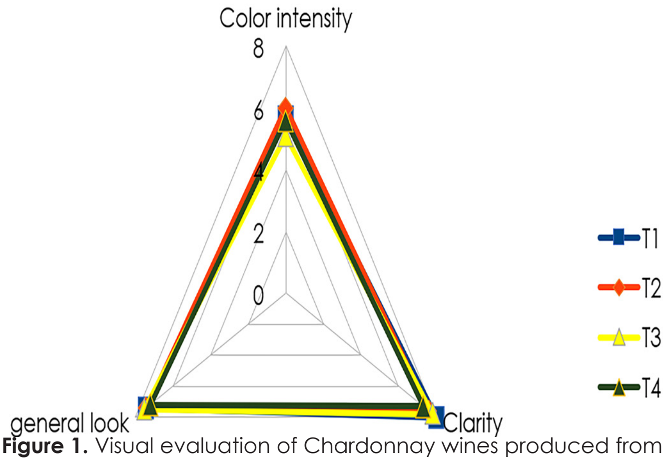

Figure 1. Visual evaluation of Chardonnay wines produced from vines with different pruning times, from the 2023 harvest, in Dom Pedrito, RS, Brazil.T1: May, 33 days before the winter solstice; T2: June, two days after the winter solstice, July: 33 days after the solstice; T4: August, 63 days after the solstice (T4).

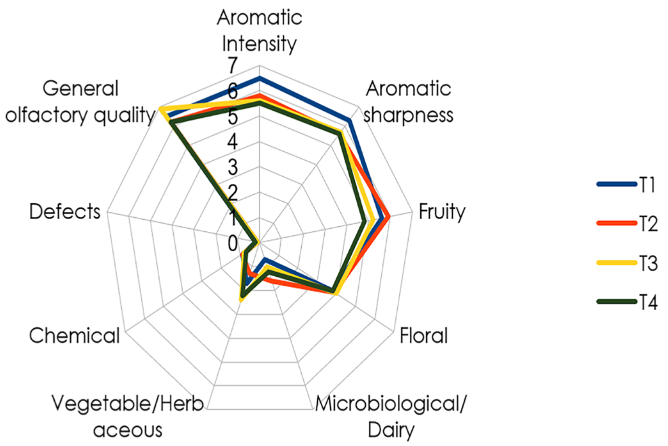

Figure 2. Olfactory evaluation of Chardonnay wines produced from vines with different pruning times, from the 2023 harvest, in Dom Pedrito, RS, Brazil. T1: May, 33 days before the winter solstice; T2: June, two days after the winter solstice, July: 33 days after the solstice; T4: August, 63 days after the solstice (T4), all in the 2022 year.

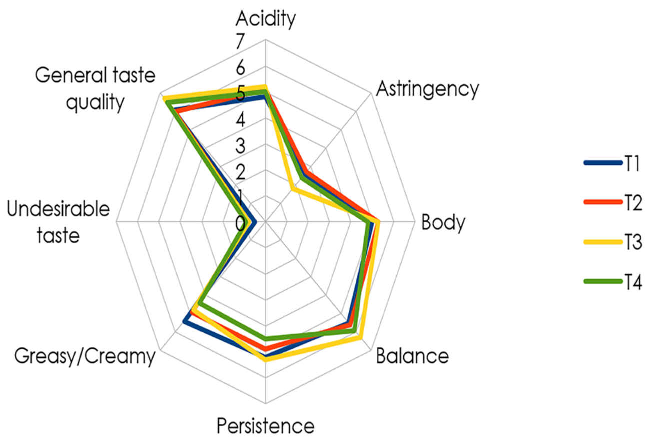

Figure 3. Taste evaluation of Chardonnay wines produced from vines with different pruning times, from the 2023 harvest, in Dom Pedrito, RS, Brazil.T1: May, 33 days before the winter solstice; T2: June, two days after the winter solstice, July: 33 days after the solstice; T4: August, 63 days after the solstice (T4), all in the 2022 year.

Conclusions

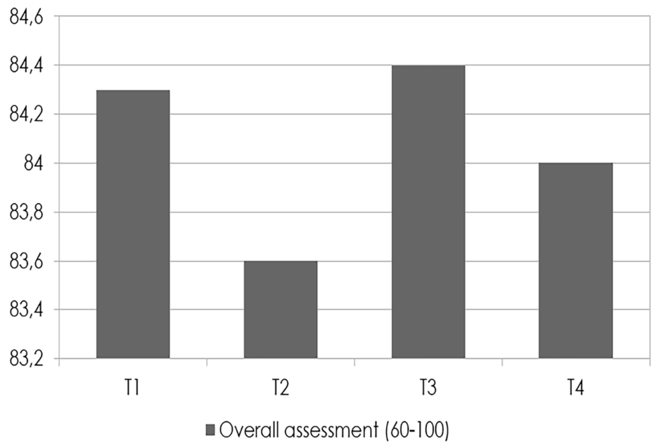

Figure 4. Global evaluation of Chardonnay wines produced from vines with different pruning times, from the 2023 harvest, in Dom Pedrito, RS, Brazil. T1: May, 33 days before the winter solstice; T2: June, two days after the winter solstice, July: 33 days after the solstice; T4: August, 63 days after the solstice (T4), all in the 2022 year.

Early pruning reduced production, but did not influence the composition of the grapes and wines. Early pruning did not change the duration of the sub-periods, nor did it bring forward the harvest.

Late pruning reduced the number of buds and reduced their sprouting, in addition to reducing the duration of the phenological cycles, without, however, bringing forward the harvest.

All treatments reduced production in relation to the control.

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