NOV 20, 2024 | 14.15 PM | SCIENTIFIC SESSION: **MALBEC I - SCIENTIFIC ORAL**

Phenology and thermal demand of Malbec grapes under double-pruning management in the subtropical conditions of Brazil

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Keywords: **double-pruning, Malbec, phenology, climate condition, season duration.**

ABSTRACT

The 'Malbec' cultivar *(Vitis vinifera)*, of French origin, has consolidated its cultivation in Argentine vineyards, in the region near the Andes Mountains and irrigated by the Mendoza River, resulting in wines with high typicity, internationally recognized, and distinguished by a large number of enthusiasts in Brazilian territory. With the expansion of viticulture, new cultivation techniques are emerging, such as double pruning, which has allowed the reversal of the vine's productive season, with fruiting and phenolic maturation occurring during the winter period in Southeast Brazil. Thus, the objective of this study was to characterize the duration of phenological stages and thermal requirement of 'Malbec' grapes, cultivated in the double pruning system, under subtropical climate conditions. The experiment was conducted in the vineyard established at Fazenda Santa Lúcia do Tietê, in the municipality of Mineiros do Tietê - São Paulo. The vines were grafted onto Paulsen 1103 rootstock, trained in a trellis system with a spacing of 3.0 x 1.0 m. Training pruning was performed in August 2022, and production pruning in February 2023. The experimental design was randomized blocks, comprising 40 vines divided into 8 blocks with 5 plants per experimental plot. The duration of phenological stages was evaluated, measured by the duration of each phenological phase, and the thermal requirement was characterized. Climatic data were obtained from a meteorological station installed in the vineyard, where the sum of degree-days from pruning to harvest was calculated. The obtained data were subjected to Descriptive Statistics analysis. The duration of the 'Malbec' productive season was 171 days after pruning (DAP). Regarding the thermal requirement, 'Malbec' presented an average of 2102.5 degree-days. The use of the double pruning technique enabled a season close to that of the same variety produced in Mendoza. Further studies are necessary to highlight the variety's behavior in repeated harvests.

Introduction:

The grape variety 'Malbec' *(Vitis vinifera)* originated in France, with a long history of cultivation. However, its presence became consolidated in Argentine vineyards, especially in the Andes Mountain region irrigated by the Mendoza River and around the city of Mendoza, notably in Luján de Cuyo (Johnson, 2008). Currently, 'Malbec' wines enjoy an emblematic status in Argentina, being widely recognized and valued in the international scene (INTA, 2007). Nevertheless, other countries have ventured into 'Malbec' production to meet the growing global demand for wines, such as Brazil (OIV, 2021). According to Eveche and Liberato (2022), Malbec red wine is the most consumed among Brazilians.

With the high demand for wine consumption, the need for increased production is linked to new producing regions. In viticulture, phenology studies are fundamental to provide an indicator of the climate of the potential production region and to understand the chemical changes that occur during fruit ripening (Callili et al., 2023). Therefore, the characterization of the duration of phenological phases is important for a better understanding of the influence of annual climatic conditions on vine development and will assist in decision-making regarding cultural and phytosanitary vineyard management, as well as in the logistics of wine raw material processing, in order to minimize fruit quality loss (Sánchez et al., 2023).

In Brazil, grape ripening and harvest occur in the summer, conditions that are not ideal for the production of fine wines. This happens due to higher rainfall, high cloud cover, high temperatures, and lower thermal amplitude. This scenario leads to the emergence of fungal diseases, compromising the health of the grapes and consequently creating unfavorable conditions for their full ripening, as there is a dilution of compounds in the berries that influence wine quality (Borghezan, 2017). For the production of quality wines, it is crucial that grapes have adequate phenolic and aromatic ripeness. To address issues of inadequate ripening and fruit health, double pruning is an indispensable management alternative for the production of fine wines (Leeuwen, 2022). The double pruning technique, pioneered by the Empresa de Pesquisa Agropecuária de Minas Gerais (EPAMIG), involves reversing the grapevine's season to the autumn and winter period (Regina et al., 2006). The technique consists of two prunings on the vine: the first pruning in mid-August for shoot formation, removing the inflorescences, and between January and February, the fruit production pruning is performed, shifting the ripening and harvesting period to the months of June to August, during the winter season with lower precipitation (Favero et al., 2008). The change in ripening and harvesting time aims to avoid the rainy season in the summer, increasing the potential for accumulation of soluble solids, organic acid balance, and other quality components for winemaking (Mota et al., 2009).

However, variables such as climate patterns can influence the duration of phenological seasons and thermal demand (Tecchio et al., 2019). Characterizing phenological stages and measuring thermal demands are used to identify the climatic potential of a particular region for grape production. In viticulture, phenology, temperature requirements, and grape maturation development are essential, with establishing a balance between soluble solids and acidity levels being fundamental (Callili et al., 2022). Double pruning is the alternative to these conditions, favoring the production of *vinifera* grapes in regions where there was no tradition of viticulture, thus creating new 'terroirs' (Pereira et al., 2020). This technology generates fine winter wines with high levels of healthiness, sugar accumulation, acidity

balance, and concentration of anthocyanins and tannins, factors responsible for the color and structure of the wine (Souza et al., 2020). In this context, the objective of the present study was to characterize the duration of phenological stages and the thermal requirement of 'Malbec', cultivated under double pruning, in subtropical climate conditions, and contribute to the production of fine winter wines in Southeast Brazil.

Materials and methods:

The experiment was conducted in the vineyard established at Fazenda Santa Lúcia do Tietê SN Bairro das Contendas, located in the municipality of Mineiros do Tietê - São Paulo, situated at 22°32'25'' S, 48°24'13'' W, and 580 meters above sea level. According to the Köppen-Geiger climate classification, the region is characterized as Cfa, a hot-summer humid subtropical climate, with the average temperature of the warmest month exceeding 22 ºC and in the coldest month below 18ºC (Cunha & Martins, 2009). The 'Malbec' grapevines were grafted onto Paulsen 1103 rootstock, trained using the trellis system with a spacing of 3.0 x 1.0 m. Training pruning was performed in August 2022, and production pruning was carried out in February 2023. The vines were arranged in planting rows with 40 plants, totaling 8 blocks with 5 plants per experimental plot, in a randomized block experimental design. The climatic data were obtained from a meteorological station owned by the vineyard property and were made available through a platform that provided meteorological data for the period of the year 2023. During the production seasons, from July to December, the average minimum temperature was 16.4°C in 2023, while the average maximum temperature was 28.8°C in 2020. The accumulated precipitation during this period was 477 mm in 2023, with a tendency for concentration in the summer months (Figure 1). The duration of each phenological phase was determined in days after pruning (DAP), through visual observations made three times a week. The periods evaluated included from Pruning to Budburst, Full bloom to Setting, Setting to Veraison, Veraison to Ripening and Total Degree Days. Thermal demand was quantified using the concept of degree-days (GD), calculating the sum of the average temperature minus 10°C multiplied by the number of days after pruning, according to the equation proposed by Winkler (1965): GD = Σ (average temperature - 10°C) × days after pruning. For the duration of phenological stages and thermal requirement, the obtained data were subjected to Descriptive Statistics analysis.

Results and discussion:

The duration of the 'Malbec' grape season from pruning to budbreak and flowering was, respectively, 11.7 and 43.2 days, and from flowering to fruit set was 3 days. It was found that the longest period between phenological stages was between ripening and harvest, which lasted on average from 95 to 171 days after pruning (DAP), respectively. Thus, the duration of the 'Malbec' grape's productive season was 171 days after pruning (DAP) (Table 1). In a study conducted by Nascimento et al. (2015) in 2015, under Brazilian semi-arid conditions, in the sub-medium of the São Francisco Valley, the Malbec variety had a season of 116 days, highlighting the influence of climate on the duration of phenological stages. In the Mendoza region, Argentina, the duration of the 'Malbec' grape season was 180 days (INV, 2004), 9 days longer than the present study (Table 1). The Mendoza region is considered a desert climate according to Köppen and Geiger, classified as BWk, with harsh winters, hot summers, very high radiation, and low cloudiness. These conditions are similar to the autumn and winter of the subtropical condition,

which presents a large thermal amplitude between day and night and low relative humidity, with an annual average of 30% (Governo de Mendoza, 2017). From February onwards, the grape harvest begins in the Argentine vineyards of 'Malbec'. During spring in Mendoza (September to November), the average temperatures range between 10°C and 25°C. In summer (December to February), temperatures can reach up to 35°C during the day and drop to around 15°C at night. In autumn (March to May), temperatures gradually decrease to a range between 5°C and 20°C. In winter (June to August), temperatures are lower, ranging between -2°C and 15°C (Mezzatesta et al., 2022). Although the double pruning harvest occurs in winter under subtropical climate conditions, there are higher temperatures compared to the traditional cultivation region in Argentina during the harvest, resulting in a 9-day reduction in the 'Malbec' harvest in the double pruning management. The phenological characterization of grapevines varies depending on the climatic conditions of each region (Farias, 2017) and has been widely studied in various wine regions in Brazil. Thus, studies establishing thermal indices are indispensable for viticultural activity, as they can demonstrate variations in thermal requirements and the number of days to complete the season for the same cultivar (Tomazetti et al., 2015). However, the expansion of vine cultivation exposes plants to climatic conditions different from those known in their place of origin, which can cause phenological alterations (Alves; Tonietto, 2017). Grapevines change their phenological behavior and the necessary thermal accumulation to complete the season when grown in locations with distinct micrometeorological conditions (Pires; Lima, 2018), which can interfere with plant growth and development, as well as the productive and qualitative characteristics of the fruits. One possible application of this research is to allow the adaptation of 'Malbec' in this subtropical region due to its adaptation. In the evaluated season, the variety produced grapes with suitable characteristics for the production of quality fine wines, showing promise for this non-traditional region in fine grape production, even when compared to the Mendoza region in Argentina. Regarding thermal requirements, the season of the 'Malbec' vine averaged 2102.5-degree days (GD), while the duration of the following phenological phases was measured in days after pruning over one production season: budburst, full-bloom, setting, veraison, and ripening were 179.8, 500.5, 56.5, 625.6, and 740.1 GD, respectively (Table 2). In the present study, the results of thermal accumulation (GD) for the 'Malbec' cultivar were very close to those found in an experiment conducted under Aw climate conditions in northeastern Brazil, with thermal requirements of 1,580.03 degree-days (Moraes et al., 2015). Double pruning, by occurring in colder months during its maturation, tends to increase thermal requirements compared to traditional cultivation regions. However, there is a scarcity of studies on the thermal requirements of the ‘Malbec’ grape variety, especially in the context of double pruning management under subtropical conditions, which is evident in the current literature. Mendoza is known for its dry, sunny, continental climate with significant daily temperature variations. These characteristics are favorable for the cultivation of 'Malbec' grapes, providing a slow and balanced ripening of the grapes. Altitude in Mendoza has a great influence on the main determinants of terroir: temperature, thermal amplitude, and luminosity (Deis & Kaiser, 2020).

The thermal requirement of the 'Malbec' grape variety in the region of Mendoza, Argentina, refers to the ideal climatic conditions for the healthy growth and

development of this variety. The average temperature during the growing season is a crucial factor in determining the success of 'Malbec' cultivation (Goldner, 2007).

Conclusion:

The duration of the 'Malbec' cultivar season was 171 days with 2102.5-degree days (GD). Under subtropical climate conditions, double pruning management in the 'Malbec' cultivar provided suitable conditions for the development of phenological stages and grape ripening.

Figure 1. Cumulative precipitation as a function of average temperature in the 2023 season.

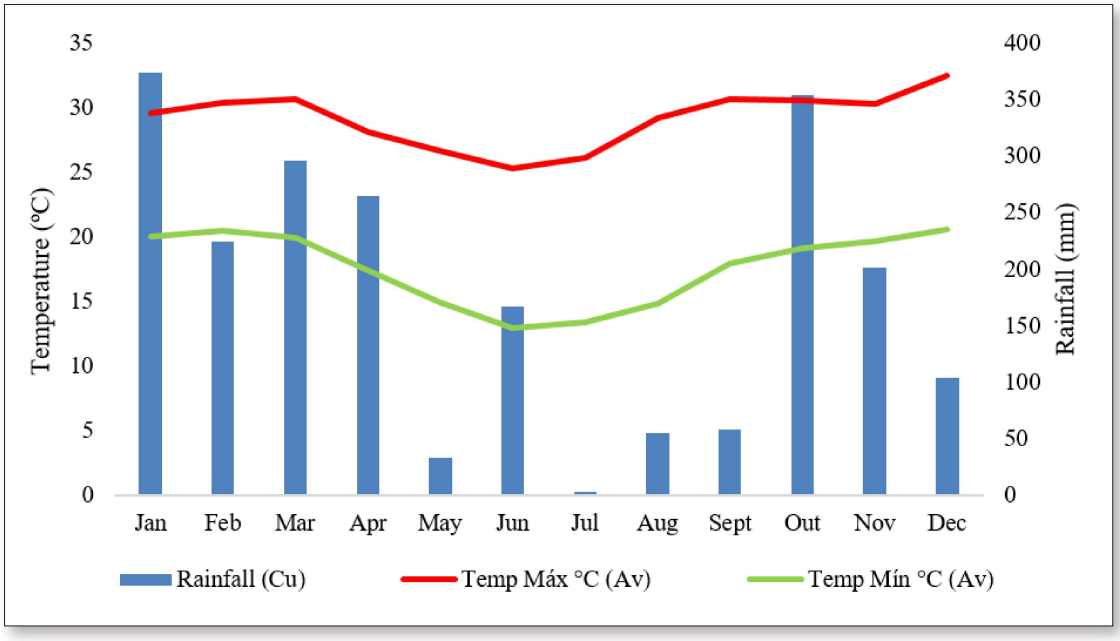

Table 1. Phenological characterization and thermal requirement of 'Malbec' grapes under double pruning management produced in subtropical conditions, counted in days after pruning (DAP).

Descriptive statistics	Budburst	Full-bloom	Setting	Veraison	Ripening
Mean	11,7	43,2	45,9	94,7	171,0
Standard Error	0,3	0,6	0,6	0,5	0,4
Standard deviation	0,8	1,6	1,7	1,3	1,2
Minimun	10,0	42,0	45,0	94,0	171,0
Maximum	12,8	46,6	49,2	96,8	171,0
CV (%)	0,7	1,4	1,4	1,1	1,0

Table 2. Characterization of the thermal requirement of 'Malbec' grapes under double pruning management at different phenological stages, produced in subtropical conditions.

Descriptive statistics	PR/BD	BD/FB	FB/ST	ST/VR	VR/RP	GD (TDD)
Mean	179,8	500,5	56,5	625,6	740,1	2102,5
Standard Error	5,0	13,9	3,0	5,0	4,1	0,2
Standard deviation	14,2	39,2	8,6	14,2	11,7	0,5
Minimun	152,1	476,9	46,0	596,2	721,2	2101,6
Maximum	200,2	586,9	63,0	633,0	746,4	2102,9
CV (%)	11,9	32,8	7,2	11,9	9,8	0,4

Legend: PR/BD: Pruning to Budburst; BD/FB: Budburst to Full bloom; FB/ST: Full bloom to Setting; ST/VR: Setting to Veraison; VR/RP: Veraison to Ripening; GD (TDD): Total Degree Days.

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