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THERMAL REGIME DURING THE GRAPEVINE'S VEGETATIVE DORMANCY IN THE BANU MĂRĂCINE VINE-GROWING AREA

Băducă Cîmpeanu Constantin[1]
[1*]University of Craiova, Faculty of Horticulture, Department Horticulture and Food Science
**Correspondence author. E-mail*: cbaduca@gmail.com

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ABSTRACT

The study conducted in the Banu Mărăcine wine-growing area during the grapevine dormancy period—covering the 2024/2025 and 2025/2026 viticultural years—has highlighted another dimension of climate change. Rising temperatures during the dormancy period can significantly impact the onset of the grapevine's growth cycle by triggering earlier budbreak. Over the last two years, the winters have been mild, with temperatures not dropping below -11°C. Throughout all six months of the season, average temperatures remained higher than the long-term multi-year averages. The primary drawback of this situation is a substantial reduction in the grapevine's resistance to low temperatures—specifically those associated with late frosts—given that the frequency of such frost events has remained constant.

INTRODUCTION

Climate change represents one of the most critical challenges of our time, as it has already reshaped, or is in the process of altering, the Earth's ecosystems. Its extensive impacts are particularly evident in the agricultural sector, which underpins global food production and is a key element of the global economy (Kotsidis et al, 2026). Among human activities, agriculture is likely to be particularly exposed to change impacts risk since the weather conditions prevailing during the crops' life cycles are the major abiotic factors for their growth, determining, therefore, the quantity and quality of agricultural production and ultimately the economic sustainability (Droulia & Charalampopoulos, 2021).

The wine sector, among the most profitable agricultural segments, has been markedly affected by the ongoing climate change impacts, such as warmer climate conditions with higher frequency of extreme temperatures and a trend of decreasing precipitation (Faralli Michele et al, 2024).

Grapevine is the most widely grown fruit crop in the world and it is cultivated on six out of seven continents, between latitudes 4° and 51° in the Northern Hemisphere and between latitudes 6° and 45° in the Southern Hemisphere. The global range of grape growing climate zones is about 10 °C (between 12 °C and 22 °C growing season average temperatures), and even narrower for premium wine quality grapes. Projections suggest that rising global temperatures will lead to a significant redistribution of the grape growing regions throughout the world. Impacts will be negative for the areas that are already teetering on being too hot for quality

grape production, while areas that were historically too cold are reaching or are projected to reach in the near future climate conditions suitable for viticulture (Tachini et al, 2023). Anthropogenic climate change has uneven impacts across the globe and throughout the year. Such unevenness poses a major challenge for human adaptation, especially for agricultural and other managed systems. Estimating effects beyond one region is chal lenging, however, because differences between regions make it difficult to know what seasonal periods of climate to compare. Both local climate and the planting decisions of a region affect the relevant periods for estimating changes in climate (Wolkovich et al, 2025).

Climate conditions are the main constraints in determining whether a specific crop is suitable to a given region and represent a crucial factor in defining the agricultural vocation of a specific area, its traditions and its economic opportunities. This is especially true for the winemaking sector, for which climate conditions establish the degree of appropriateness of a specific grapevine variety to a specific site and also determine the year-to-year yield, vintage quality and value. Optimal conditions for wine production depend on a vulnerable equilibrium between several climatic variables, for example temperature, solar radiation, precipitation, humidity, wind and evapotranspiration. Among them, temperature is arguably the most important factor, as it influences grapevine phenology by determining its development, from budbreak to fruit maturity, as well as affecting vine physiology and fruit metabolism/composition (Sgubin et al, 2023). Given the strong influence of temperature on grapevine phenology, most conventional phenological models use chilling and forcing concepts to represent dormancy release and subsequent growth. These models typically estimate winter chill accu mulation followed by spring heat requirements, while sim pler approaches such as Growing Degree Days (GDD) rely solely on temperature accumulation from a fixed starting date. As a result, temperature is the primary predictor in most phenological models. Despite their widespread use, uncertainties remain in rep resenting dormancy and chilling accumulation. The inter action between chilling fulfilment and heat requirements varies among cultivars and climates, and different chilling formulations can lead to substantially different phenologi cal projections. Consequently, dor mancy processes remain a major source of uncertainty in phenological modelling (Stoica, 2015, Didevarasl et al, 2026).

The impact of climate change on spring frost risk has been discussed controversially in the scientific literature in recent years. Generally, spring frost occurs when budburst precedes the date of the last frost event in the spring of a given year. Under future climate conditions, both events are projected to occur earlier. Although some studies suggest that the last frost events will move to earlier dates at a faster rate than budburst and, hence, reduce spring frost risk in the future, other studies were inconsistent or predicted increased risks for spring frost damage, indicating a high degree of uncertainty (Santos et al, 2020). Ongoing climate warming is projected to further intensify its influence on global viticulture over the coming decades. Many wine regions have already experienced warming equivalent to nearly 100 additional growing degree days over the past 70 years. Climate projections under moderate (RCP 4.5) and high-emission (RCP 8.5) scenarios indicate continued temperature increases ranging from 0.6–0.7 °C (RCP 4.5) to over 2.0 °C under high-emission scenarios (RCP 8.5) by 2050 across major viticultural zones in Europe, North America, and other regions. While these projections indicate substantial impacts on grapevine phenology, fruit composition, and regional

suitability, their magnitude and direction vary across models, emission scenarios, and local environmental conditions, introducing significant uncertainty in regional predictions (Madhuchanda et al, 2026, Costea et al, 2025).

The timing of the phenological stages for grapevines varies between seasons, largely controlled by climatic conditions. Notwithstanding this seasonal variation, a general advancement in the timing of three of these grapevine phenological stages, flowering, veraison and maturity has been reported in recent decades with temperature being a major driver for these shifts in phenological timing. The situation for budburst has been less clear and observed changes in budburst timing have varied, with both advancement and delays in timing being reported. The effect of temperature on budburst is more complex because two temperature signals are required. Winter chilling is required to break the endodormancy phase of the bud and increased temperatures during this period have been shown to delay budburst. The competing temperature effect is that increasing spring temperatures advance budburst timing, so budburst timing is therefore influenced by the balance of these two effects (Cameron et al, 2022, Cichi et al, 2026).

MATERIAL AND METHODS

In this study, we monitored temperature trends during the grapevine's dormancy period – from October 1st to March 31st of the following year – across the 2024/2025 and 2025/2026 viticultural years in the Banu Mărăcine wine area, Dealurile Craiovei vineyard. The meteorological data are provided by the weather station located in the vineyard, which is integrated into the vineyard's drip irrigation system. We recorded daily maximum and minimum temperatures, using them to calculate the average temperature for the day, the month, or the entire period.

The recorded temperature values and the indices calculated based on them for the 2024/2025 and 2025/2026 viticultural years were compared with the multiannual average values calculated for a 90-year period (1901–1990), taken from the ANM archive.

RESULTS AND DISCUSSIONS

An analysis of the data regarding average temperatures during the vegetative dormancy period, compared to the long-term average, shows that in each season, all six months were warmer than the long-term average. Specifically, for the entire dormancy season, the long-term average was 3.2°C; in the first season (2024/2025), the average temperature was double that figure (6.5°C), while in the second season (2025/2026), it was also higher (5.5°C), though not quite as high as in the previous year (table 1 and figure 1).

An analysis of the average temperatures for each month reveals that October was significantly warmer in 2024 (13.4°C) than in 2025 (11.5°C) and the long-term average (11.4°C). Conversely, in November, the situation was reversed: it was significantly warmer in 2025 than in 2024—a year in which the temperature was very close to the long-term average.

compared to the long-term average. In 2024, the average temperature for December was 7.0°C; in 2025, while lower (5.6°C), it was still significantly higher than the long-term average (0.1°C). Consequently, during these two seasons, December did not function as a winter month. January and February were the coldest months during the vegetative dormancy period, both within the two years of the study and over the 90-year historical span. While the long-term average was below

freezing for both months (-2.6°C in January and -0.5°C in February), during the two years under study, only one month in each year recorded a sub-zero average temperature: February in 2025 (-0.6°C) and January in 2026 (-0.8°C).

March was also significantly warmer than usual. Compared to a long-term average of 5.1°C, the temperature reached 9.8°C in 2025 and 7.6°C in 2026.

Table 1

Average temperature in the grapevine's vegetative dormancy season compared to the 90-year average

Month	Multi-year average (1901-1990), ^{0}C	Season 1 ^{0}C	Season 2 ^{0}C
October	11,4	13,4	11,5
November	5,5	5,6	7,6
December	0,1	7,0	5,6
January	-2,6	3,6	-0,8
February	-0,4	-0,6	1,6
March	5,1	9,8	7,6
Season average	**3,2**	**6,5**	**5,5**

(Season 1: 2024/2025; Season 2: 2025/2026)

In October 2024, there were 15 days with a maximum temperature of at least 20 °C, whereas in October 2025, there were only 3 such days. In 2024, the maximum temperature for October reached 26 °C, while the lowest daily maximum was 13 °C. In October 2025, the maximum temperature was 23 °C, with the lowest daily maximum being 6 °C. The minimum temperature for October was 2 °C in 2024 and 1 °C in 2025. In October 2024, there were two days with a minimum temperature of 15 °C, while in October 2025, the highest daily minimum was 12 °C.

In November 2024, the maximum temperature was 23 °C, with only one day exceeding the 20 °C threshold; the lowest daily maximum was 3 °C, occurring on the coldest day of the month – which also saw the absolute minimum for the month (-5 °C) and was the only day with a negative average temperature (-1 °C). In total, there were 8 days that month with a negative minimum temperature. By contrast, in November 2025, the maximum temperature was 20 °C, and the absolute minimum was 0°C, recorded on two separate days. In December 2024, the maximum temperature reached 16 °C, while in December 2025, it reached 12 °C. The lowest temperatures recorded during these months were 3 °C in 2024 (observed on two occasions) and -1 °C in 2025 – the latter occurring on the only day with a sub-zero maximum temperature. Furthermore, December 2025 included 4 days with a maximum temperature of 0 °C; one of these days also saw the absolute minimum temperature for both seasons (-5 °C).

In December 2024, there were 5 days with a minimum temperature of 0 °C and 6 days with sub-zero minimum temperatures, whereas in December 2025, there were 4 days with a minimum temperature of 0 °C and 12 days with sub-zero minimum temperatures. These data clearly highlight that the month of December did not exhibit the characteristics of a winter month.

In January 2025, maximum temperatures ranged between 2 °C and 18 °C; consequently, there were no days with a sub-zero maximum temperature. In January

2026, maximum temperatures were lower, ranging from -7 °C to 10 °C, with 8 days recording a sub-zero maximum and another 3 days reaching a maximum of 0 °C.

Regarding minimum temperatures, in January 2025 they ranged between -8 °C and 7 °C, while in January 2026 they ranged between -10 °C and 3 °C. In January 2025, there were 20 days with sub-zero minimum temperatures, two days with a minimum of 0 °C, and 9 days with a minimum above 0 °C; in January 2026, there were 21 days with a sub-zero minimum, 6 days with a minimum of 0 °C, and only 4 days with a minimum above 0 °C.

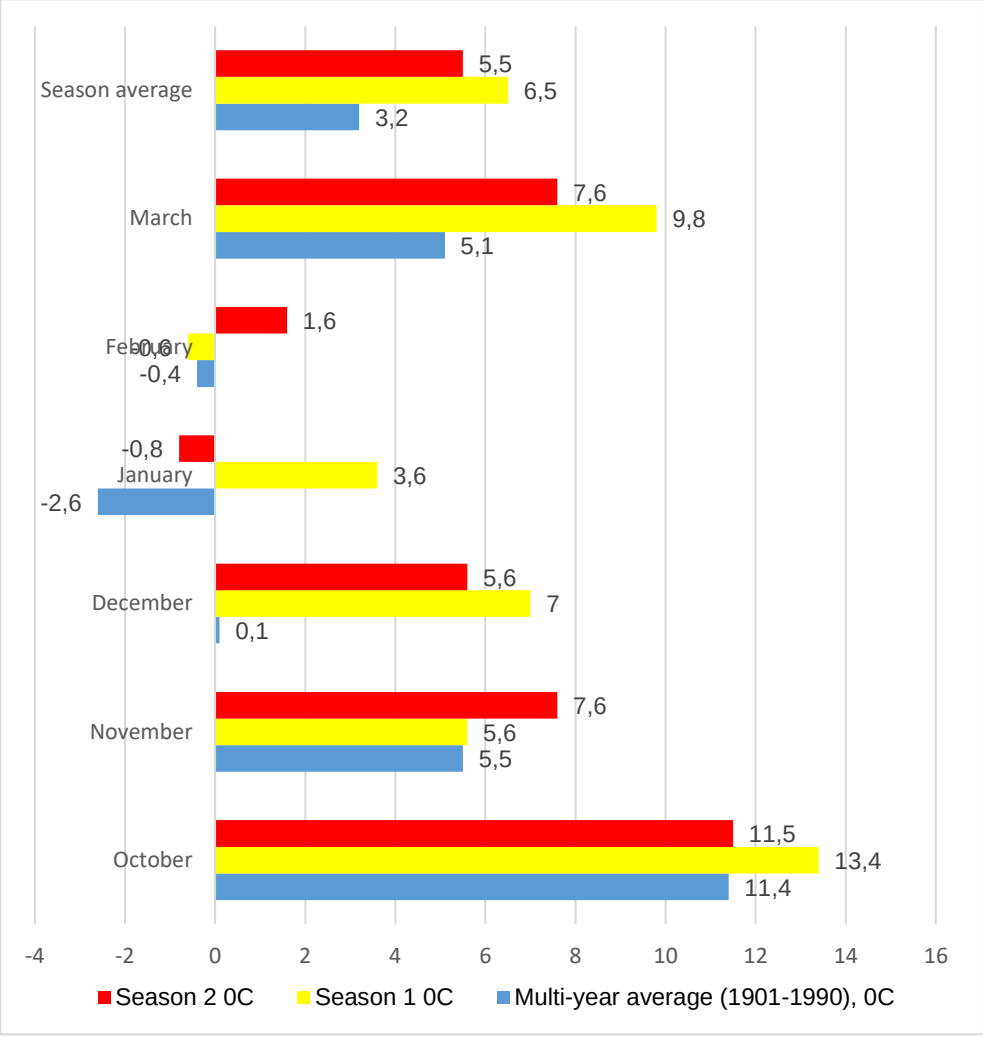


Figure 1. Average temperature in the grapevine's vegetative dormancy season compared to the 90-year average

The absolute minimum for January 2026 was -10 °C, recorded on two separate days—on both of which the maximum temperature was also below 0 °C.

The lowest daily average, however, was -8 °C, recorded on a day when the minimum was -9 °C and the maximum was -7 °C. In January 2025, the absolute minimum was -8 °C, recorded over two consecutive days.

In January 2025, there were only 3 days with a sub-zero average temperature, with the coldest day of the month having an average temperature of -3 °C. In contrast, January 2026 saw 17 days with a sub-zero average temperature, including a 7-day consecutive stretch from January 16th to 22nd during which the minimum temperature remained below 0 °C.

In February 2025, the maximum temperature reached 13 °C on the very first day of the month; this was the warmest day, boasting the highest average temperature, as the minimum was also positive. Unlike the previous month—which saw no days with a sub-zero maximum—this month had two days with a maximum of 0 °C and eight days with a sub-zero maximum, including four consecutive days between February 16 and 19. In contrast, February 2026 was warmer than the previous month; there were only 3 days with a sub-zero daily maximum, and another 4 days with a maximum of 0 °C. In February 2026, the highest temperature reached was 13 °C, with two other days reaching 12 °C and two days reaching 10 °C.

Regarding minimum temperatures, in February 2025 there were only 5 days with a temperature above 0°C—specifically the first 3 and the last 2 days of the month. From February 4th to the 26th, there was a 23-day consecutive stretch with sub-zero minimum temperatures. The lowest temperature recorded was -11 °C, occurring on the coldest day of the month; that day also had a sub-zero maximum, resulting in a daily average temperature of -6 ^{o}C. Conversely, in February 2026, there were only 14 days with a sub-zero minimum temperature, the lowest being -10 °C, recorded on two days early in the month. Additionally, there were 5 days with a minimum temperature of 0 °C, while 9 days had a minimum temperature above 0 °C.

Table 2

Temperature limits during the grapevine dormancy period

Month	Season 1		Season 2	
	Temperature min. ^{0}C	Temperature max. ^{0}C	Temperature min. ^{0}C	Temperature max. ^{0}C
October	2	26	1	23
November	-5	23	0	20
December	-4	16	-5	12
January	-8	18	-10	11
February	-11	13	-10	13
March	-7	22	-2	13

Extreme negative temperatures (<-15 °C) during winter are likely to cause permanent damage to wood and winter buds, possibly leading to vine death. Impact of negative winter temperatures depend on many parameters like genotype, environment, cultural practices, duration of frost exposure, and tissue hydration. Temperatures below −2.2 ^{o}C after budbreak can damage young shoots and severely reduce production without, however, killing the vines (de Rességuier et al., 2020).

In March 2025, maximum temperatures ranged between 2 °C and 22 °C, while in March 2026, they ranged between 2 °C and 17 °C. In March 2025, there

were 3 days with a minimum temperature below 0 °C; one of these was the only day of the month when the average temperature was also below 0 °C. In March 2026, there were only two days with an average temperature below 0 °C—specifically the first two days of the month—followed by two other days with a minimum temperature of 0 °C; apart from those, there were no days with an average temperature below 0 °C that month.

In March 2025, there were 17 days with an average temperature above 10 °C, whereas in March 2026, there were only two such days.

CONCLUSIONS

High temperatures during the grapevine's dormancy period are a direct consequence and clear evidence of climate change; this trend is expected to exert an increasingly significant impact on viticulture in the coming decades. The two winters covered by the study were notably mild, with an absolute minimum temperature of -11 °C—a level that causes no damage to grapevines. Consequently, while there was no risk of frost for two consecutive years, these temperatures—which far exceed long-term averages—may carry other negative implications. First of all, a number of pests can survive the winter more easily because the cold no longer sufficiently reduces their biological reserves, and they encounter much more favorable conditions for resuming their biological cycle earlier. This can lead to a greater number of generations and, consequently, the need for a higher number of treatments.

Another drawback concerns the risk of damage from late frosts, should budbreak occur earlier—given that the grapevine's resistance to freezing temperatures decreases once the growing season has begun.

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