ANNALS OF THE UNIVERSITY OF CRAIOVA

Series: ✓*Biology*
✓*Horticulture*
✓*Food products processing technology*
✓*Environmental engineering*

Vol. XXXI (LXVII) - 2026

INFLUENCE OF CLIMATIC CONDITIONS ON PHENOLOGY AND THE PHYSICAL AND PHYSICOCHEMICAL PARAMETERS OF GRAPES FROM RED WINE CULTIVARS IN THE OPRIȘOR–MEHEDINȚI AREA

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Keywords: *grapevine, phenology, berry mass, grape ripening, climatic variability*

ABSTRACT

During the 2025 growing season, the performance of Fetească neagră, Pinot noir, Merlot and Cabernet Sauvignon was assessed in the Oprișor–Mehedinți wine-growing area, using 10 vines per cultivar. Climatic conditions, phenology, changes in berry mass, sugar accumulation and must acidity were monitored. Mean annual temperature was approximately 14.1 °C, 1.7 °C above the climatic reference, while precipitation totalled 556.6 mm. Pinot noir was the first to reach véraison, whereas Fetească neagră had the earliest ripening/harvest period. At final harvest, sugar concentrations reached 271 g/L in Merlot, 270 g/L in Cabernet Sauvignon, 265 g/L in Fetească neagră and 249 g/L in Pinot noir; titratable acidity ranged from 4.2 to 4.7 g/L H_2SO_4. The results highlight cultivar-specific differences in technological ripening under the conditions of the study year.

INTRODUCTION

Grapevine (Vitis vinifera L.) displays considerable ecological plasticity, which has facilitated its cultivation across regions with diverse climatic and soil conditions (Pastore et al., 2022). Nevertheless, yield and quality performance depend not solely on the genetic potential of cultivars but also on its interaction with the environment and viticultural practices (Costea & Căpruciu, 2022). In this respect, the concept of terroir integrates soil and climatic characteristics, plant material and human intervention, accounting for the distinctive features of wine production in a given area (Deloire et al., 2005; Matei et al., 2015; Van Leeuwen & Seguin, 2006).

The ecological characteristics of each wine-growing area shape the expression of cultivar biological potential through interactions between soil and climate conditions and grapevine physiological processes. From this perspective, the ecophysiological approach to the plant–terroir relationship emphasizes the need to match cultivar requirements with local natural resources (Carbonneau, 2003). Cultivar selection and the adaptation of viticultural practices to these characteristics help express the distinctive identity of the crop and enhance local quality potential (Ubalde et al., 2010).

In the context of climate change, relationships among the components of the vineyard ecosystem are becoming increasingly important (Căpruciu et al., 2024). Rising temperatures, changes in precipitation distribution and more frequent extreme weather events may affect grapevine water status, physiological processes and grape ripening dynamics (Costea, 2006; Schultz & Jones, 2010). IPCC assessments (2023) indicate multiple changes in the climate system, with regionally differentiated effects. Consequently, some areas may become more suitable for viticulture, whereas others may experience excessive temperatures during ripening, with implications for grape composition and wine quality (Cardell et al., 2019).

Grapevine responses to climatic variability differ according to cultivar and the local soil and climatic characteristics. Temperature and water availability influence phenological progression, sugar accumulation and the evolution of compounds contributing to oenological potential (Jones, 2013; Ramos & de Toda, 2020). Research conducted in Romania highlights the importance of terroir for the characteristics of Fetească neagră grapes and wines (Dobrei et al., 2018), as well as grapevine responses to variable climatic conditions (Costea et al., 2023). Studies of Cabernet Sauvignon clones in the Oltenia wine-growing region likewise underline the relevance of evaluating ampelographic and bioproductive traits under local conditions (Cichi et al., 2024; Costea et al.,2025).

Accordingly, understanding the variability of environmental factors and relating it to cultivar performance provides a basis for selecting and adapting viticultural practices to sustainably exploit local potential (Neethling et al., 2017; Van Leeuwen et al., 2019). This study examines the performance of Fetească neagră, Pinot noir, Merlot and Cabernet Sauvignon in the Oprișor–Mehedinți wine-growing area, focusing on the relationship between soil and climatic conditions, cultivar characteristics and grape quality as a foundation for the oenological potential of the crop.

MATERIAL AND METHODS

Observations and measurements were carried out during the 2025 growing season in a family-owned vineyard located in the Oprișor–Mehedinți wine-growing area. The plant material comprised 40 vines, 10 for each of four red wine cultivars: Fetească neagră, Merlot, Cabernet Sauvignon and Pinot noir. The vines were trained on a medium-height system and pruned using semi-trunk Guyot training, with a bud load of 20 buds per vine.

The study aimed to characterize climatic conditions during the observation period, monitor phenological development and assess the biological and bioproductive responses of the four cultivars.

Climatic data for the experimental period were obtained from the Meteoblue online weather platform (www.meteoblue.com) and processed at ten-day and monthly intervals to identify climatic features relevant to grapevine cultivation. Phenological monitoring covered the onset of budburst, flowering, véraison and grape ripening.

Quantitative and qualitative assessments included the mass of 100 berries (g), volume of 100 berries (mL), must density, potential alcohol (% vol.), pH, soluble sugars (g/L) and titratable acidity (g/L H_2SO_4). Successive measurements allowed ripening dynamics to be monitored for each cultivar.

RESULTS AND DISCUSSIONS

Climatic characterization of the Oprișor area

Analysis of the 1979–2025 climate series reveals an upward trend in mean annual temperature in the Oprișor area, particularly after 2000. According to Meteoblue data, mean annual temperature in 2025 was approximately 14.1 °C, representing a positive anomaly of 1.7 °C, while precipitation totalled approximately 556.6 mm, 30.4 mm below the reference level. Alternating warm periods and unevenly distributed rainfall, especially in summer, provide relevant context for interpreting grape ripening, although water stress cannot be demonstrated without soil-water measurements (Figure 1).

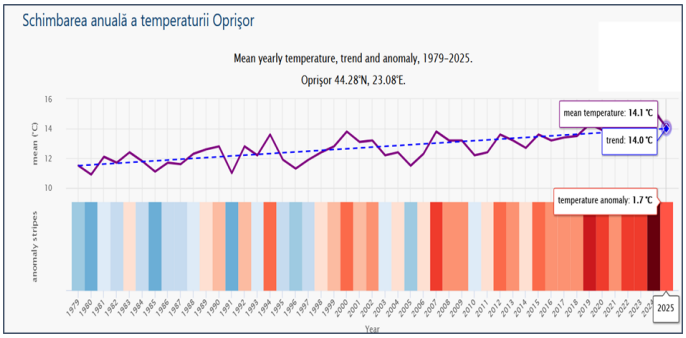


Figure 1. Changes in mean annual temperature in the Oprișor area (1979–2025). Climatic data: Meteoblue.

Compared with the temperature trend, rainfall showed greater interannual variability. Both annual precipitation and its distribution during berry growth and ripening are important for interpreting cultivar performance in 2025.

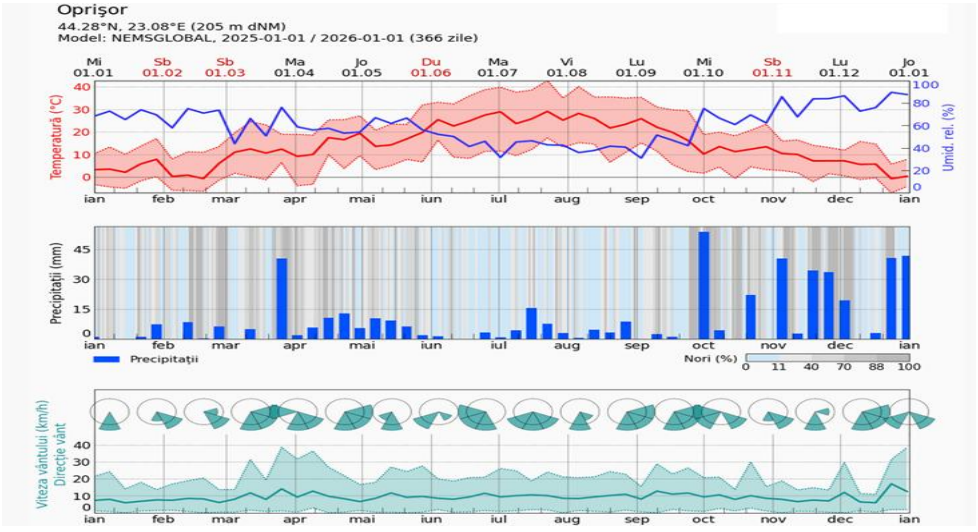


Figure 2. Temperature, precipitation and wind speed during 2025 (Meteoblue)

Assessment of climatic conditions during the experimental period indicates high temperatures throughout the active growing season, with a marked increase during June–August (Figure 2). Ten-day temperature, precipitation and wind-speed data describe conditions typical of the Oprișor wine-growing area, with frequently high maximum temperatures in summer accompanied by low and unevenly distributed rainfall. These conditions are relevant to interpreting grapevine performance because they coincide with important stages of berry development, véraison and the accumulation of compounds contributing to grape quality.

Phenology of the studied cultivars

Phenological observations revealed minor differences among cultivars at the beginning of the growing season: flowering occurred between 1 and 5 June 2025 in all four cultivars. Differences became more pronounced at véraison and ripening.

Pinot noir reached véraison first (5–10 August), followed by Fetească neagră (10–15 August), Cabernet Sauvignon (10–20 August) and Merlot (15–25 August). In contrast, the ripening/harvest periods began earliest in Fetească neagră (3–10 September), followed by Pinot noir (9–16 September), Cabernet Sauvignon (12–19 September) and Merlot (19–26 September)- figure 3. The differing order of véraison and ripening indicates distinct cultivar-specific developmental rates under the conditions of the study year.

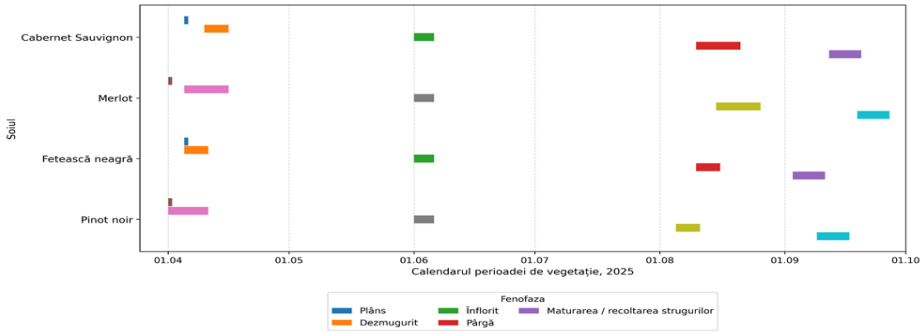


Figure 3. Calendar of the main phenological stages of the studied cultivars, Oprișor, 2025.

Ripening dynamics and quantitative and qualitative parameters

Ripening was monitored through six successive measurements per cultivar, performed between 7 August and 26 September 2025 according to cultivar phenology. Changes in berry mass and volume, sugar content and acidity are presented using actual measurement dates to enable comparison of trends and identification of periods with more pronounced changes.

In Cabernet Sauvignon, sugars increased from 157 g/L (14 August) to 270 g/L (19 September), while acidity decreased from 8.3 to 4.7 g/L H_2SO_4. Merlot increased from 132 g/L (21 August) to 271 g/L (26 September), alongside a decline in acidity from 12.0 to 4.6 g/L H_2SO_4. In Fetească neagră, values changed from 156 g/L sugars and 9.2 g/L H_2SO_4 (7 August) to 265 g/L and 4.4 g/L H_2SO_4 (10 September). In Pinot noir, sugars rose from 156 g/L (13 August) to 249 g/L (16 September), while acidity declined from 13.4 to 4.2 g/L H_2SO_4.

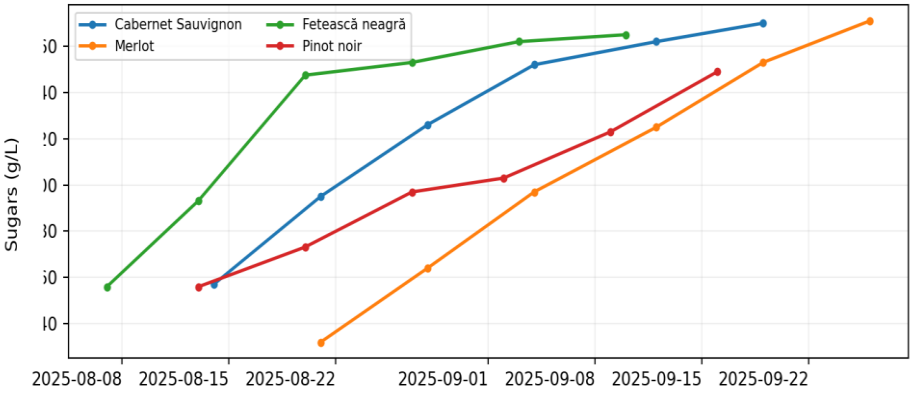


Figure 4. Changes in sugar concentration (g/L) from véraison to ripening, Oprișor, 2025.

Sugar accumulation continued until harvest, although the pattern differed among cultivars. In Cabernet Sauvignon, the mass of 100 berries decreased from a maximum of 134 g (4 September) to 127 g (19 September), while in Merlot it declined from 125 g (12 September) to 119 g (26 September)- figure 4. In Fetească neagră and Pinot noir, berry mass continued to increase until the final measurement- figure 5. In Cabernet Sauvignon, the volume of 100 berries changed from 130 mL (4 September) to 125 mL (19 September), and in Merlot from 119 mL (12 September) to 117 mL (26 September). In Fetească neagră and Pinot noir, both mass and volume increased until the final measurement. These contrasting patterns, alongside sugar accumulation, may reflect both berry growth and changes in berry water content; the underlying mechanisms cannot be distinguished from the measured parameters alone- figure 5.

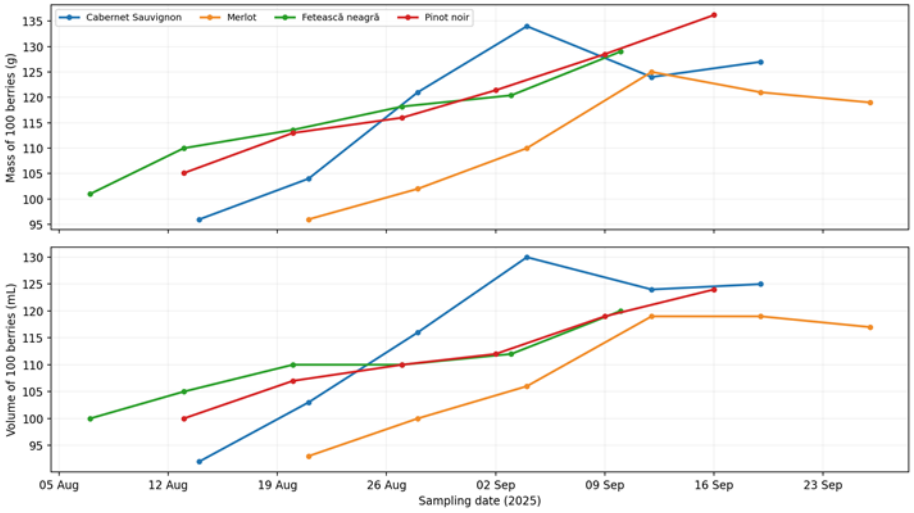


Figure 5. Changes in mass (A) and volume (B) of 100 berries in the studied cultivars, Oprișor, 2025.

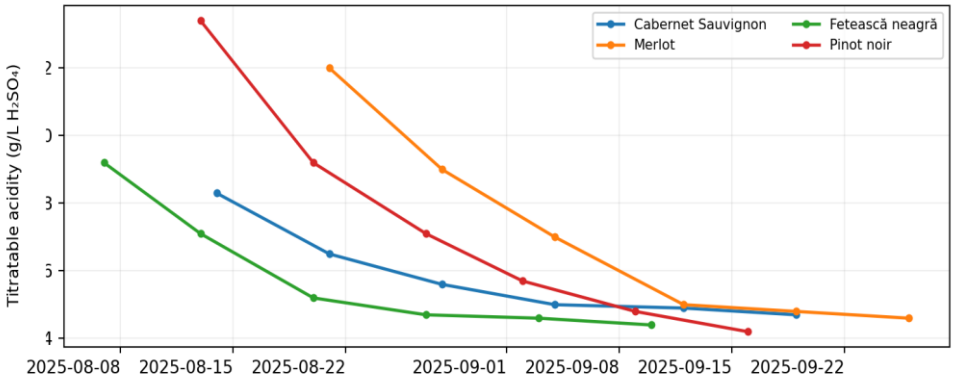


Figure 6. Changes in titratable acidity (g/L H_2SO_4), Oprișor, 2025.

The decline in acidity was more pronounced during the first part of the monitored periods, with final values converging among cultivars (4.2–4.7 g/L H_2SO_4)- figure 6. Together with sugar accumulation, this indicates progress towards technological maturity, but does not allow direct assessment of phenolic maturity because anthocyanins and tannins were not measured.

Table 1

Changes in selected grape quality parameters in red wine cultivars grown in the Oprișor wine-growing area at two harvest dates representing different degrees of ripeness, 2025

Studied cultivars	**indicators**	**Harvest dates**	
Cabernet sauvignon	**Harvest date**	**04.09.2025**	**19.09.2025**
	Must density	1,101	1,115
	Sugars (g/L)	252	270
	Potential alcohol (% vol.)	14,8	15,8
	pH=	3,47	3,4
	Total acidity (g/L H_2SO_4)	5	4,7
Merlot	**Harvest date**	**12.09.2025**	**26.09.2025**
	Must density	1,07	1,11
	Sugars (g/L)	225	271
	Potential alcohol (% vol.)	13,2	15,94
	pH=	3,45	3,4
	Total acidity (g/L H_2SO_4)	5	4,6
Feteasca neagra	**Harvest date**	**28.08.2025**	**10.09.2025**
	Must density	1,103	1,109
	Sugars (g/L)	247	265
	Potential alcohol (% vol.)	14,4	15,5
	pH=	3,55	3,42
	Total acidity (g/L H_2SO_4)	4,7	4,4
Pinot noir	**Harvest date**	**09.09.2025**	**16.09.2025**
	Must density	1,097	1,106
	Sugars (g/L)	223	249
	Potential alcohol (% vol.)	13,1	14,6
	pH=	3,48	3,4
	Total acidity (g/L H_2SO_4)	4,8	4,2

Comparison of the two harvest dates (Table 1) shows increases in sugars and potential alcohol in all cultivars. Merlot showed the largest increase in sugars between 12 and 26 September (46 g/L), whereas Fetească neagră had already reached 247 g/L on 28 August. Differences in harvest dates require ripening trends to be interpreted in relation to each cultivar's phenology.

Alongside sugar accumulation, titratable acidity decreased in all cultivars. The numerical sugar-to-acidity ratio, calculated using the reported units (g/L and g/L H_2SO_4, respectively), ranged at final harvest from 57.4 (Cabernet Sauvignon) to 60.2 (Fetească neagră). These values are intended solely for comparisons within this experiment and are not, on their own, sufficient to assess oenological quality.

From an oenological perspective, potential alcohol values at final harvest indicate favourable conditions in 2025 for red wine cultivars grown in the Oprișor area. They reached 15.8 % vol. in Cabernet Sauvignon, 15.94 % vol. in Merlot, 15.5 % vol. in Fetească neagră and 14.6 % vol. in Pinot noir. High potential alcohol values reflect substantial sugar accumulation supported by favourable heliothermal conditions.

CONCLUSIONS

In 2025, temperatures in the Oprișor area exceeded the climatic reference and annual precipitation was slightly below average and unevenly distributed. Under these conditions, all four cultivars showed increasing sugar concentrations and declining acidity during ripening.

Phenology revealed cultivar-specific differences: Pinot noir was the first to reach véraison, Fetească neagră showed the earliest ripening/harvest period, and Merlot the latest.

At final harvest, sugars reached 271 g/L in Merlot, 270 g/L in Cabernet Sauvignon, 265 g/L in Fetească neagră and 249 g/L in Pinot noir, while acidity ranged from 4.2 to 4.7 g/L H_2SO_4. These findings indicate substantial technological ripening potential but do not permit a comprehensive ranking of oenological quality. Changes in berry mass and volume differentiated the cultivars, with late declines in Cabernet Sauvignon and Merlot and continued increases in Fetească neagră and Pinot noir.

The results describe cultivar performance during a single growing season, based on 10 vines per cultivar. Confirmation of these trends requires multi-year monitoring and measurements of phenolic maturity.

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