

EVALUATION OF THE TECHNOLOGICAL POTENTIAL OF WINE GRAPE VARIETIES IN THE CONTEXT OF CLIMATE CHANGE IN THE DEALU MARE VINEYARD

Liliana PÎRCĂLABU, Steliana Paula BARBU, Marian ION,
Georgeta TUDOR, Alexandra BUCUR

Research and Development Institute for Viticulture and Enology Valea Călugărească,
2 Valea Mantei Street, Valea Călugărească Commune, Prahova County, Romania

Corresponding author email: stelianap.barbu@gmail.com

Abstract

Climate change involves the adaptation of crop systems to the effects of climate variability, which influence vines, given the dependence of weather changes during the growing season, as well as increasing the duration and intensity of meteorological phenomena. The researches were carried out in the Valea Călugărească viticultural center within three viticultural plantations with the varieties Sarba, Negru aromat and Feteasca neagra. In the last 25 years, the climate has changed in the meaning that heating resources increased and the rainfall resources decreased. These changes in the viticultural climate have determined an earlier development of the vegetative phenophases, especially the early phenophases and grape ripening (by approximately 7-14 days), which has particularly influenced the quality of grape production. Regarding the yield of grape production, it was found that the average rate of decrease was 0.86 kg/vine, the loss of acidity by 0.99 g/l and a higher accumulation of sugar 30-60 g/l.

Key words: climatic change, grapevine, phenology, grape production.

INTRODUCTION

In recent decades, increasing attention has been given to climate change and its associated risks. Given the importance of grapes for wine production and the current circumstances of climate change, it is essential to avoid modification of composition and freshness of wine concerning consumer preferences.

The impact of climate change on grape production is difficult to predict due to the large number of variables involved in grape cultivation.

Viticulture could benefit from increased atmospheric CO₂ levels, but at the same time, excessive heat, drought, and solar radiation can have negative effects on grapevines.

Climate change not only affects yield and production quality but can also change the progression of the vine's vegetative phenophases.

Higher temperatures caused by climate change (ex. + 2°C) encourage the ripening period to occur during a warmer time of the year (ex. + 2°C), resulting in an overall increase of + 4°C during grape ripening (Alston JM et al., 2011; Delay E et al., 2015). Currently, with the increase in the average air temperature and solar

radiation, grapes are harvested about two weeks earlier than the period from 1970-1999.

Climate studies conducted in the Romanian vineyard region have highlighted a trend of changing viticultural climate over the past two decades, manifested by an increase in temperature regime and an unfavorable distribution of precipitation during the growing season of the vine (Busuioc et al., 2004).

The intensity and duration of soil drought phenomena vary depending on the complex interaction of agrometeorological factors, particularly temperature, which is undoubtedly a strong driving force for the development of grapevines (Viviane Becart, 2022; Jones and Alves, 2012), extremely high maximum temperatures in the air and soil, associated with low relative air humidity (atmospheric drought), a deficient precipitation regime influences the vegetative behavior of grapevines and consequently, the quality of grape musts and the composition of wines.

Although the grapevine is considered a plant that is resilient to water stress, these phenomena can significantly affect the vegetative development of the plants, their productive potential, and especially the quality of the grape

harvest, with direct implications for the quality and typicity of the wines produced in the viticultural areas DOC (Tate, 2001; Jones G.V. et al., 2005; Drappier et al., 2017).

MATERIALS AND METHODS

The study aimed to evaluate the impact of climate change on the technological potential of the Negru aromat (NA) and Fetească neagră (FN) grape varieties, which are part of the basic assortment for the production of quality red wines typical of the Dealu Mare vineyard, Sarba variety for aromatic white wines and table grape varieties Victoria and Xenia. Climate data used in this analysis are for the Research Institute for Viticulture and Enology Valea Călugărească station for 2000 to 2024. The studied viticultural climate parameters were: air temperature, precipitation, solar radiation, and relative humidity.

The characteristics of the precipitation regime were analyzed based on the criteria of Hellmann, which highlights the characteristics of periods with drought years and those with rainy years through mathematical calculations.

Assessments were made on the grape harvest from a quantitative and qualitative point of view at the technological maturity, at the same stage for all the experimental variants.

The following analyses were performed: sugar content - determined by refractometry (OIV, 2021a); total acidity - determined by titration with NaOH (OIV, 2021b), gluco-acidimetric index = sugar ratio/total acidity (expressed in g/l tartaric acid).

Grape quality parameters were defined through correlation analysis.

To establish the correlations between phenolic maturity and the technological characteristics of grapes, the Spearman correlation coefficient was calculated, based on the relative position of a value compared to the others.

RESULTS AND DISCUSSIONS

The meteorological data recorded in the period 2000-2024 show a thermal regime characterized by annual average temperatures oscillating between 11.4°C and 14.0°C. Compared to the multi-year average, years 2022, 2023 and 2024 they recorded an increase in the annual average

temperature of 0.3°C, respectively 1.2°C. Concerning the average temperature registered throughout the vegetation period, the variations oscillated between + 0.2°C (2023) and +1.7°C, (2024), average annual temperatures with 0.3°C, respectively 1.2°C (Figure 1).

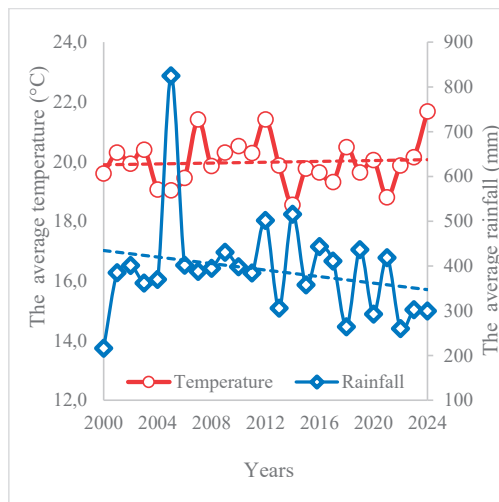


Figure 1. The average temperature (°C) and rainfall (mm) during the vegetative period, from 2000-2024

Regarding the frequency of occurrence of absolute maximum temperatures (>30°C), in the year 2022 in the month of June increased by 3.8 days, respectively with 19.8 days (2024), (26 days compared to the multi-year average of 6.2 days). During July and August, the frequency of appearance of absolute maximum temperatures exceeding 30°C, has been increased by 19.6% in the year 2022, respectively 26.6% (2024) (25.4 days cumulative average over the period 1970-1999, 45 days in the year 2022 and 52 days in the year 2024).

The Valea Călugărească viticultural center is characterized by a precipitation variation spectrum within the IS₁ class, resulting in conditions of moderate drought. The variation of precipitation amounts during the growing season is characterized by a maximum in the year 2005 (824.7 mm) and a minimum in the year 2000 (216 mm). The analysis of the data reveals that the categories of years with the greatest weight are those in the normal rating category composed of 10 years, with a weight of 40% and precipitation between 583.3 and 712.7 mm/year, the category with the slightly dry rating, composed of 2 years, with a weight of 8%

and precipitation between 532.5 and 554.8 mm/year and dry with a weight of 12% and precipitation between 467.7 mm and 505.2 mm, and the category with the very dry rating, composed of 2 years, with a weight of 8% and precipitation between 364.1 mm and 424.3 mm. Percentage-wise, for the analyzed time interval, 32% of the years are characterized by a rating from slightly dry to extremely dry, 40% of the years are characterized by normality, and 28% of the years are characterized by a rating from slightly wet to extremely wet. The duration of sunshine during the growing season recorded significant increases of +285 hours (2023) and +316 hours (2024), against a background of reduced relative air humidity by 7% (2024) (Figure 2).

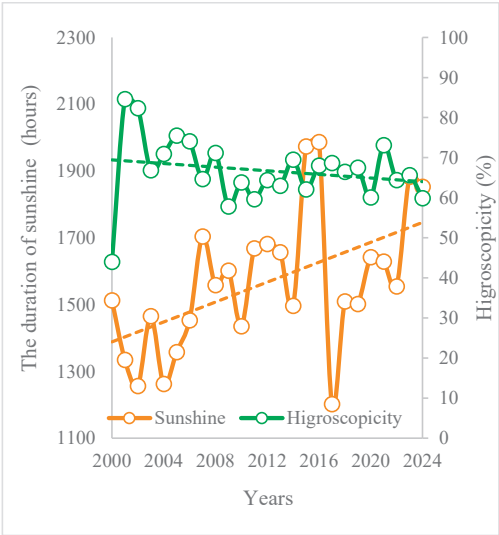


Figure 2. The average duration of sunshine (hours) and the hygrospecificity (%) during the vegetative period from 2000-2024

Analysis over a 25-year period (2000-2024) of varietal phenology Feteasca neagra, Negru aromat and Sarba, the analysis highlights that budburst started towards the beginning of April, April 10th (2024) - April 18th-20th (2000), flowering at the beginning of June, June 9th (2024) - June 20th (2000), early ripening in the first half of August, August 7th (2024) and the second half of August, August 21st (2000), and grape ripening was reached at the beginning of September, September 2nd (2024), and September 20th (2000), respectively.

Furthermore, a uniform progression of vegetative phenophases was noted across all varieties.

These changes in the viticultural climate have led to an earlier progression of vegetative phenophases, particularly early ripening and grape ripening (by approximately 7-14 days), which has notably influenced the quality of grape production.

In the case of the Feteasca neagra variety, grape production showed variations ranging from 3.524 kg/vine (in 2000) to 1.926 kg/vine (in 2024), an average reduction of 0.063 kg/vine/year, while the sugar content registered an increase of 3.28 g/l/year sugar, with variations between 174.8 g/l (2000) and 256.7 g/l (2024). Regarding acidity, the average value decreased by 0.076 g/l/year (Figure 3).

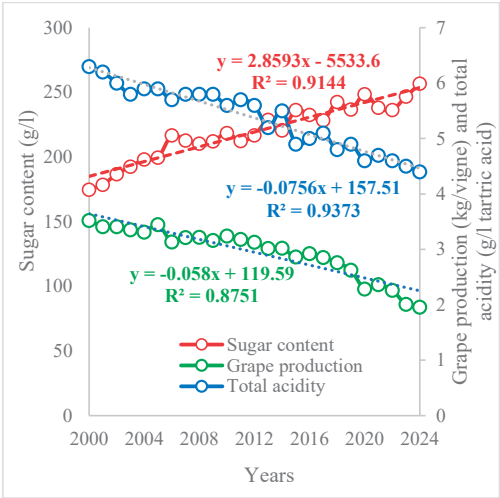


Figure 3. The grape production (kg/vine), sugar content (g/l) and total acidity (g/l tartaric acid) of the Feteasca neagra variety

The high sugar content (256.7 g/l) and total acidity (4.4 g/l tartaric acid) corresponding to the year 2024, resulted in the gluco-acidimetric index reaching a value of 58.4.

Significant positive correlations were identified between sunshine duration and sugar content (+0.57), as well as negative correlations with grape production (-0.50) and total acidity (-0.53) (Table 1).

Based on the significance of correlation coefficients, coefficients with a value greater than 0.42 are considered significant.

Table 1. Correlation coefficients between climatic parameters, grape production, and its quality in the Feteasca neagra variety

Climatic parameters	Grape production	Sugar content	Total acidity
Temperature (°C)	-0.12	0.13	-0.07
Rainfall (mm)	0.36	-0.22	0.31
The duration of sunshine (hours)	-0.50	0.57	-0.53
Higroscopicity (%)	0.12	-0.21	0.17

In the case of the Negru aromat variety, grape production showed oscillations between 2.022 kg/vine hub (2024) and 3.682 kg/vine hub (2002). Over the course of 25 years, the average grape production decreased by 0.066 kg/vine hub/year, while the sugar content increased by 2.99 g/l/year. A decreasing trend was also observed in total acidity, with approximately 0.080 g/l/year (Figure 4).

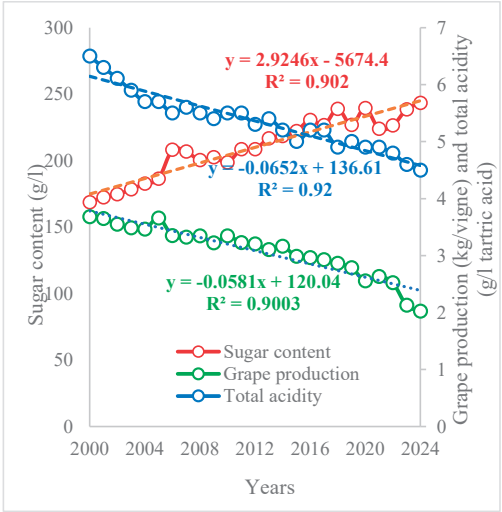


Figure 4. The grape production (kg/vine hub), sugar content (g/l) and total acidity (g/l tartaric acid) of the Negru aromat variety

The high sugar content (243.4 g/l) and total acidity of 4.5 g/l tartaric acid resulted in the gluco-acidimetric index reaching values well above those optimal for producing quality wines, with a value of 54.09 (2024). The obtained results demonstrate the existence of positive correlations between sunshine duration and sugar content (+0.57), as well as negative correlations with grape production (-0.55) and total acidity (-0.54) (Table 2).

Table 2. Correlation coefficients between climatic parameters, grape production, and its quality in the Negru aromat variety

Climatic parameters	Grape production	Sugar content	Total acidity
Temperature (°C)	-0.19	0.11	-0.10
Rainfall (mm)	0.37	-0.22	0.14
The duration of sunshine (hours)	-0.55	0.57	-0.54
Higroscopicity (%)	0.23	-0.21	0.15

The same decreasing trend was observed in the grape production of the Sarba variety, with variations between 3.986 kg/vine hub (2000) and 2.512 kg/vine hub (2024), as well as in the total acidity of the must, from 6.7 g/l tartaric acid (2000) to 4.4 g/l tartaric acid (2024). The sugar content showed an average increase of 3.200 g/l/year, registering contents from 162.8 (2000) to 242.8 g/l (2024) (Figure 5).

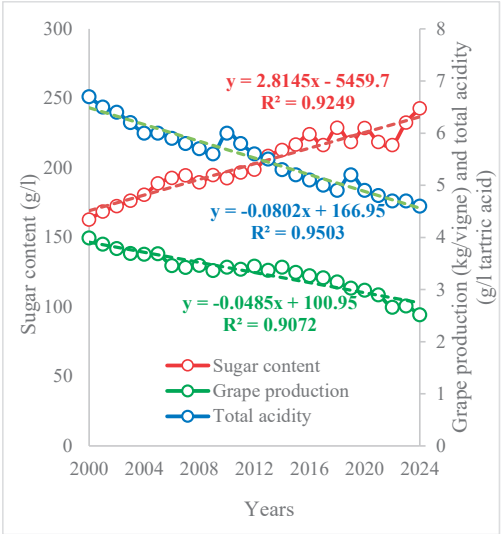


Figure 5. The grape production (kg/vine hub), sugar content (g/l) and total acidity (g/l tartaric acid) of the Sarba variety

The gluco-acidimetric index values obtained for the Sarba variety are well above those optimal for producing high-quality aromatic wines, with a value of 52.8 (2024). Significant positive correlations were also identified between sunshine duration and sugar content (+0.58), as well as negative correlations with grape production and total acidity (-0.51), (Table 3).

Table 3. Correlation coefficients between climatic parameters, grape production, and its quality in the Sarba variety

Climatic parameters	Grape production	Sugar content	Total acidity
Temperature (°C)	-0.18	0.09	-0.02
Rainfall (mm)	0.28	-0.17	0.19
The duration of sunshine (hours)	-0.51	0.58	-0.51
Higroscopicity (%)	0.19	-0.18	0.15

The excessive thermal regime and severe decrease in soil humidity, evident since the early ripening period of the 2024 grape harvest, had a favourable effect on sugar accumulation in table grapes, while grape production was negatively influenced due to the berry shrivelling phenomenon caused by a greater water loss through transpiration compared to that supplied through soil water absorption. Thus, the grape production of the Victoria variety decreased from 4.100 kg/vine hub (2000) to 2.266 kg/vine hub (2024), (Table 4), and in the case of the Xenia variety, the variations were from 6.000 kg/vine hub (2000) to 4.216 kg/vine hub (2024) (Tabel 5).

Table 4. Grape production and its quality in the Victoria variety

Period	Grape production (kg/vigne)	Sugar content (g/l)
2000-2009	3.553	160.6
2010-2019	3.015	169.6
2020	2.684	173.2
2021	2.576	175.4
2022	2.532	178.8
2023	2.438	182.6
2024	2.266	189.6

Table 5. Grape production and its quality in the Xenia variety

Period	Grape production (kg/vigne)	Sugar content (g/l)
2000-2009	5.568	161.4
2010-2019	4.902	171.7
2020	4.516	176.8
2021	4.502	178.4
2022	4.482	182.6
2023	4.424	184.2
2024	4.216	192.8

The sugar content recorded in table grape varieties had an average value of 160.6 g/l (2000-2009) and 189.6 g/l (2024) for the

Victoria variety, and from 161.4 g/l (2000-2009) to 192.8 g/l (2024) for the Xenia variety.

The reduced volume of rainfall in the summer months caused the soil water reserve in 2024 to drop below 50% of the plant's available moisture range, starting in August. These values persisted throughout September, manifesting the phenomenon of grape shrivelling. Based on the analysis of time series, long-term trends of climate change were identified, predicting a decrease in grape production for the analyzed varieties, an increase in sugar content (a trend that can be explained by higher temperatures and more hours of sunshine), as well as a decrease in acidity (Table 6).

Table 6. Long-term trends of climate change impact on grape production and its quality in the analyzed varieties

Variable	Tendency
Grape production FN	 -0.058/an
Grape production NA	 -0.058/an
Grape production Sarba	 -0.048/an
Sugar content FN	 +2.86/an
Sugar content NA	 +2.92/an
Sugar content Sarba	 +2.81/an
Total acidity FN	 -0.075/an
Total acidity NA	 -0.065/an
Total acidity Sarba	 -0.080/an

All trends are extremely statistically significant ($p<0.05$), meaning that the changes observed over time are not random.

The decrease in production and acidity, as well as the increase in sugar, are confirmed as real tendencies.

Based on prediction models (Random Forest & XGBoost), we determined which climatic parameters most significantly influence grape production and its quality.

Production is primarily influenced by precipitation (30%) and temperature (24-26%), confirming the impact of water and heat on the grape harvest (Table 7).

Table 7. The prediction model (Random Forest) for grape production of the analyzed varieties

Climatic parameters	Feteasca neagra	Negru aromat	Sarba
Temperature (°C)	0.26	0.24	0.22
Rainfall (mm)	0.32	0.28	0.30
The duration of sunshine (hours)	0.20	0.22	0.21
Higroscopicity (%)	0.22	0.26	0.27

Sugar content is largely determined by sunshine duration (40-45%) and hygroscopicity (30%), confirming that more sun → more sugar (Tabel 8).

Table 8. The prediction model (Random Forest) for the sugar content of the analyzed varieties

Climatic parameters	Feteasca neagra	Negru aromat	Sarba
Temperature (°C)	0.15	0.18	0.16
Rainfall (mm)	0.10	0.12	0.08
The duration of sunshine (hours)	0.45	0.42	0.40
Higroscopicity (%)	0.30	0.28	0.36

Acidity is most influenced by hygroscopicity (75-81%), suggesting that air humidity plays a significant role (Tabel 9).

Table 9. The prediction model (Random Forest) for the total must acidity of the analyzed varieties

Climatic parameters	Feteasca neagra	Negru aromat	Sarba
Temperature (°C)	0.07	0.06	0.08
Rainfall (mm)	0.05	0.04	0.06
The duration of sunshine (hours)	0.10	0.09	0.11
Higroscopicity (%)	0.78	0.81	0.75

CONCLUSIONS

The data suggests that the climate is changing in the direction of higher sugar content, but with lower production and reduced acidity. This could affect the quality of wines produced from these varieties.

Precipitation and temperature are the most significant climatic parameters affecting grape production, with sugar concentration being influenced by duration of sunshine and total must acidity by hygroscopicity.

Long-term trends indicate a decrease in production with values ranging from 0.048 kg/vine hub/year (Sarba) to 0.058 kg/vine hub/year for Feteasca neagra and Negru aromat, as well as a decrease in total acidity by 0.065

g/l/year (Negru aromat), 0.075 g/l/year (Feteasca neagra) and -0.080 g/l/year for the Sarba variety. The sugar content of the must will register increasing trends with +2.81 g/l/year (Sarba), 2.86 g/l/year (Feteasca neagra) and 2.92 g/l/year for Negru aromat. Statistically, the long-term trends are very significant (p<0.05).

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