Scientific Papers. Series B, Horticulture. Vol. LXIX, No. 2, 2025
Print ISSN 2285-5653, CD-ROM ISSN 2285-5661, Online ISSN 2286-1580, ISSN-L 2285-5653

THE BEHAVIOR OF GRAPE VARIETIES FOR RED WINE IN THE VALEA CALUGAREASCA WINE CENTER

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Abstract

The researches were carried out in the period 2020-2024, at the wine center Valea Calugareasca within six viticultural plantations with the varieties Feteasca neagra, Cabernet Sauvignon, Merlot, Negru aromat, Novac and Olivia, particularly valuable varieties from an oenological point of view, which are part of the basic assortment for the production of quality red wines. In the last 4 years, the climate has changed in the sense that the thermal regime has increased and the water deficit was accentuated especially during the vegetation period of the vine. The level of the sugars in grape juice has varied between 270.4 g/l (Negru aromat), 254.4 g/l (Novac) and 237 g/l (Merlot), but secondary metabolites such as anthocyanins, negatively affected by high temperatures and with oscillations between 1854 mg/l (Novac), 1540 mg/l (Cabernet Sauvignon) and 1155 mg/l (Olivia). Regarding the content in total polyphenols, the maximum was obtained by the varieties Olivia (81 mg/l), Novac (78 mg/l), Negru aromat (73 mg/l) compared to the variety Cabernet Sauvignon, in which the content in total polyphenols was only 41 mg/l.

Key words*: grape production, sugars; varieties, anthocyanins, total polyphenols.*

INTRODUCTION

Red wines are among the most appreciated types of wines due to their complex sensory characteristics, high content of phenolic compounds, and aging potential. The origin and grape varieties used play an essential role in defining wine quality, influencing its chemical composition, tannin structure, and aromatic intensity (Jackson, 2008).

In recent decades, research in oenology has highlighted the importance of genetic and climatic factors in the accumulation of anthocyanins, polyphenols, and sugars in grapes. These compounds are essential for the color, stability, and balance of red wines (Ribéreau-Gayon et al., 2006). High temperatures and prolonged sun exposure can intensify anthocyanin synthesis, while regions with moderate precipitation favor a balance between sugars and acidity (Matthews & Nuzzo, 2007).

Beyond genetic and climatic influences, viticultural and technological practices play a crucial role in determining the final quality of red wines. Studies show that strategies such as yield regulation, leaf management to optimize sun exposure, and selecting the optimal harvest time can significantly impact the accumulation of secondary metabolites in grapes (Jones & Davis, 2017).

Romania has a significant viticultural diversity, cultivating both indigenous varieties, each with distinct enological potential. Recent studies indicate that varieties such as Fetească neagră, Cabernet Sauvignon, and Merlot have a high content of polyphenols and anthocyanins, giving them great potential for producing high-quality wines (Teodorescu et al., 2011). Moreover, international market trends show an increased preference for wines with high phenolic compound content due to their health benefits and distinctive character (González-SanJosé et al., 2008).

Climate change has a significant impact on vineyards and, consequently, on the quality of red wines. The rise in global temperatures influences vine phenology, leading to earlier ripening periods and affecting the balance between sugars and acidity. Higher temperatures favor sugar accumulation and acidity reduction, which can impact wine structure and aging potential (Jones et al., 2005). Additionally, variations in precipitation can

alter the extractability of phenolic compounds, resulting in significant differences in color intensity and tannin stability (van Leeuwen & Darriet, 2016). Adapting grape varieties to new climatic conditions is essential for maintaining wine quality, requiring the selection of clones resistant to thermal stress and the use of optimized viticultural practices to mitigate the effects of climate change.

This study aims to analyze the compositional differences among various red wine grape varieties, offering insights into their potential and the influence of climatic conditions on wine quality.

MATERIALS AND METHODS

The study aimed to compare and interpret quality characteristics to highlight the potential of each variety in producing high-quality wines.

The studied varieties included Cabernet Sauvignon (CS), Fetească neagră (FN), Merlot (M), Negru aromat (NA), Novac (N), Negru moale (NM), Negru vârtos (NV), and Olivia (OL).

Climate data used in this analysis were collected from the Research Institute for Viticulture and Enology Valea Călugărească station for the period 2020 to 2024. The analyzed viticultural climate parameters included air temperature, precipitation, and solar radiation.

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

The following analyses were performed: sugar content, determined by refractometry (OIV, 2021a); total acidity, determined by titration with NaOH (OIV, 2021b); and the glucose-acidimetric index, calculated as the sugar/total acidity ratio (expressed in g/L of tartaric acid).

The analyzed data originate from measurements conducted on grapes from different varieties, evaluating total and extractable anthocyanin content, total polyphenols, extractability, and seed maturity.

The statistical analysis includes mean comparisons, variance analysis (ANOVA), and principal component analysis (PCA) to identify significant differences among varieties.

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RESULTS AND DISCUSSIONS

Overall, the years 2020-2024 were characterized by high heliothermal resources combined with low water availability, particularly during the veraison-ripening period of the grapes.

A specific feature of these years was the occurrence of extremely high air temperatures during the summer months, frequently exceeding 35ºC and even reaching 40ºC (Table 1).

Table 1. The climatic parameters of average temperature, precipitation and duration of sunshine in the period 2020-2024

Year	Average temperature °C	Rainfall mm	Sunshine duration hours
2020	15.7	20.1	1642
2021	17.9	18.8	1629
2022	18.5	19.9	1555
2023	19.9	20.2	1883
2024	20.6	21.7	1912

Characteristic for the period 2022-2024 are the very high air temperatures and the low volume of rainfall in the summer months, which caused the grape wilting phenomenon to occur frequently in the grape plantations during the berry ripening-grape ripening period.

The frequency of the occurrence of risk factors ranged between 30% (2022) and 80.6% (2020 and 2024) (Table 2).

Table 2. The frequency of appearance of the risk factor in the period 2020-2024

Year	2020	2021	2022	2023	2024
May	3.2				
June	30.0	23.3	33.3	20.0	86.7
July	61.3	71.0	74.2	84.0	90.3
August	80.6	48.4	74.2	77.0	80.6
September	33.3	3.3	6.7	26.7	36.7

Grape production per vine varied significantly among varieties, indicating differences in individual vine productivity.

Regarding grape yield, variations ranged between 1.956 kg/vine (2024) and 2.364 kg/vine (2021) for the Fetească neagră variety (Table 3).

The Cabernet Sauvignon and Merlot varieties show the highest levels of production, confirming their high production potential, also presenting the highest F-statistical values, which confirms a strong variation in production between years.

Table 3. The grape production (kg/vine) of the analyzed varieties in the period 2020-2024

Year/grape varieties	2020	2021	2022	2023	2024
FN	2.284	2.364	2.264	2.008	1.956
CS	2.986	2.896	2.656	2.684	2.512
M	3.012	2.994	2.856	2.812	2.736
NA	2.554	2.632	2.522	2.128	2.022
N	2.748	2.726	2.638	2.526	2.368
OL	2.689	2.624	2.526	2.312	2.228
NM	2.528	2.432	2.364	2.329	2.167
NV	2.436	2.402	2.361	2.286	2.128

On the other hand, the Novac and Negru moale varieties show moderate variability, but remain significant, indicating a possible impact of climatic factors (Table 4).

Table 4. The statistical significance of grape productions in the period 2020-2024

Grape varieties	F-Statistic	p-Value	Statistical significance
FN	7.85	<0.01	***
CS	9.12	<0.01	***
M	8.45	<0.01	***
NA	5.43	<0.05	**
N	5.62	<0.05	**
OL	6.98	<0.01	***
NM	6.27	<0.05	**
NV	7.14	<0.01	***

$p < 0.01$ (very significant difference)
$p < 0.05$ (significant difference)

The potential for accumulation of sugars in the must, a variety characteristic influenced by the climatic factors during the ripening period of the grapes, was variable from one variety to another.

Thus, the Negru aromat variety had the highest sugar content in 2024 (270.4 g/l), 256.8 g/l (Cabernet Sauvignon), 252.6 g/l (Merlot), 248.2 g/l (Fetească neagră) (Table 5).

The lowest sugar contents were recorded in 2020, respectively 228.9 g/l (Negru aromat), 218.6 g/l (Cabernet Sauvignon), 216.2 g/l (Novac). The sugar content of musts increased with the increase in temperature and with the decrease in grape production.

Table 5. The sugar content of grape must (g/l) of the analyzed varieties in the period 2020-2024

Year/grape varieties	2020	2021	2022	2023	2024
FN	206.8	212.6	224.8	238.6	248.2
CS	218.6	224.8	238.6	242.2	256.8
M	210.4	216.9	234.8	240.6	252.6
NA	228.9	236.4	248.6	256.2	270.4
N	216.2	228.8	238.6	246.2	254.4
OL	212.4	214.6	226.8	232.4	236.4
NM	198.6	206.8	212.4	216.8	224.4
NV	186.8	199.6	206.8	212.6	216.8

The total acidity of the must in the climatic conditions specific to the period 2020-2024 oscillated within very wide limits, with a pronounced variability for this property.

The total acidity showed variations between 3.4 g/l acid tartar (2024) in the Novac variety and 4.1 g/l acid tartaric in the Negru moale variety (Table 6).

Table 6. The total acidity of grape must (g/l tartric acid) of the analyzed varieties in the period 2020-2024

Year/grape varieties	2020	2021	2022	2023	2024
FN	4.6	4.6	4.2	3.9	3.5
CS	4.4	4.2	4	3.8	3.6
M	4.6	4.2	4.2	3.9	3.7
NA	4.9	4.6	4.3	3.8	3.6
N	4.6	4.4	4.0	3.6	3.4
OL	4.6	4.4	4.2	4.0	3.9
NM	5.2	4.8	4.6	4.4	4.1
NV	5.2	4.6	4.4	4.0	3.8

Correlating these data with the climatological analysis, it is observed that high temperatures and longer duration of exposure to the sun favored the accumulation of sugars, while higher rainfall contributed to maintaining a balanced acidity, essential for the freshness of red wines.

In 2024, the gluco-acidimetric index took over very high values, with variations from 75.1 (Negru aromat), 74.8 (Novac), 71.3 (Cabernet Sauvignon) (Table 7).

Phenolic maturity makes it possible to forecast the quality of red wines and to model grape winemaking technologies in the direction of improving the phenolic structure of wines.

The best seed maturity was achieved by the Olivia, Negru aromat and Fetească negră varieties (Table 8).

Table 7. The gluco-acidimetric index of the analyzed varieties in the period 2020-2024

Year/grape varieties	2020	2021	2022	2023	2024
FN	45.0	46.2	53.5	61.2	70.9
CS	49.7	53.5	59.7	63.7	71.3
M	45.7	51.6	55.9	61.7	68.3
NA	46.7	51.4	57.8	67.4	75.1
N	47.0	52.0	59.7	68.4	74.8
OL	46.2	48.8	54.0	58.1	60.6
NM	38.2	43.1	46.2	49.3	54.7
NV	35.9	43.4	47.0	53.2	57.1

Table 8. The phenolic maturity of the analyzed varieties in the period 2020-2024

Varieties of grape	Total anthocyanins	Extractible anthocyanins	Extractability
FN	1130	792	71
CS	1650	765	48
M	1296	794	67
NA	836	685	86
N	2326	1562	59
OL	1242	1086	95
NM	256	156	72
NV	472	264	57

Polyphenols influence the structure of wine and its ageing capacity. The results show that the varieties Negru aromat, Novac and Olivia have the highest values of total polyphenols, indicating a high tannic potential (Table 9).

Table 9. The total polyphenols and the seed maturity of the analyzed varieties in the period 2020-2024

Varieties of grape	Total polyphenols	Seed maturity
FN	45	28
CS	45	28
M	49	34
NA	78	67
N	82	25
OL	87	52
NM	28	81
NV	48	79

The significant differences confirm the variability of anthocyanin and polyphenol content between varieties, with less impact on extractability.

Regarding the content of total anthocyanins, extractable anthocyanins and extractability, the results obtained show significant differences between varieties, some presenting a high content of total anthocyanins (Fetească neagră and Cabernet Sauvignon), while others have lower values, but with a high extractibility (e.g. Novac, Negru moale). Extractability is a key factor in establishing the coloring intensity of wines. Varieties with high extractibility can generate wines with a more stable and intense color. There is a contrast between the varieties, some having a high extractibility, which suggests an easy extraction of phenolic compounds in the must.

It is known that the maturity of the seeds influences the balance of tannins and the astringent sensation of the wine. Varieties with more mature seeds tend to offer finer tannins, favoring the achievement of a balanced and harmonious wine.

Climatic factors play a key role in the accumulation of anthocyanins and polyphenols, thus influencing the quality of red wines. High temperatures favor the biosynthesis of anthocyanins, but can reduce their extractibility, while excessive rainfall can dilute phenolic compounds. In regions with warm climates, varieties such as Cabernet Sauvignon and Fetească neagră accumulate a high content of anthocyanins, which gives them an intense and stable color.

The results obtained in the main compound analysis indicate that PC1 explains 60% of the variation and PC2 explains 28%, which allows a clear separation of varieties according to anthocyanin and polyphenol content. Varieties with high anthocyanin values (Fetească Neagră, Cabernet Sauvignon) are located on the positive side of PC1, while varieties with high polyphenols (Olivia) are clearly differentiated on PC2 (Figure 1).

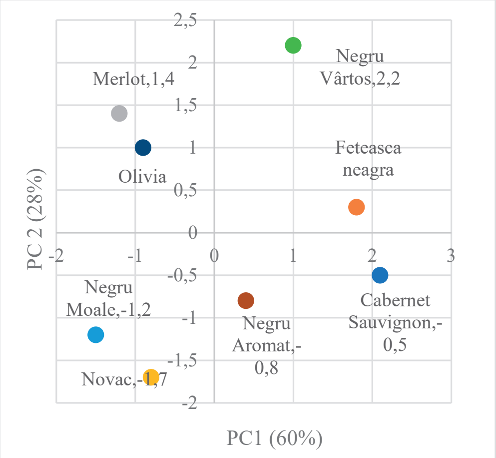

Figure 1. The distribution of the grape varieties according to PC1 and PC2

The highest anthocyanin content is found in the Novac (2326 mg/L) and Cabernet Sauvignon (1650 mg/L) varieties, which gives them a high potential for wines with an intense color and long stability.

PC1 separates varieties rich in polyphenols and anthocyanins (Novac, Cabernet Sauvignon) from those with a lower content (Merlot, Negru aromat).

PC2 reflects differences in tannin extractibility and phenolic maturity, indicating that Negru vartos and Merlot varieties have finer tannins and better extractability, while Novac and Negru moale exhibit more aggressive tannins and reduced extractability.

Feteasca neagra and Cabernet Sauvignon are positioned close to each other, suggesting similar phenolic characteristics and a good balance between structure and acidity.

Varieties on the negative side of PC2 (Novac, Negru aromat) tend to have a different phenolic profile, making them more suitable for distinct wine styles.

In order to understand the relationships between the analyzed variables, the analysis of the correlations between the phenolic characteristics of the grape varieties was performed.

The results show that there is a strong positive correlation between total anthocyanins (TA) and extractable anthocyanins (EA) ($r = 0.85$, $p < 0.01$), suggesting that varieties with a high content of total anthocyanins also have a high extractibility of them. Also, total polyphenols (TP) correlate positively with total anthocyanins and extractable anthocyanins ($r = 0.76$, $p < 0.05$), indicating that total polyphenols are influenced by these pigments. On the other hand, seed maturity (SM) has insignificant negative correlations with the other variables, which shows that seed maturity does not directly influence anthocyanin or polyphenol levels (Table 10).

The anthocyanin content is strongly influenced by temperature and rainfall, confirming the climatic impact on the stability of the pigments. Total polyphenols correlate significantly with sugars and acidity, suggesting a direct relationship between phenolic maturity and the chemical composition of grapes.

Extractability is largely determined by the chemical structure defined by PCA analysis, indicating a complex profile of phenolic interactions.

Table 10. The correlations between phenolic characteristics of the grape varieties in the period 2020-2024

Characte-ristic	TA	EA	EXTR*	TP	SM
AT	1.00	0.85***	0.42*	0.76**	-0.30
AE	0.85***	1.00	0.58**	0.62**	-0.25
EXTR	0.42*	0.58**	1.00	0.38	-0.15
PT	0.76**	0.62**	0.38	1.00	-0.20
MS	-0.30	-0.25	-0.15	-0.20	1.00

*EXTR-Extractibility
$p < 0.01$ (very significant correlation)
$p < 0.05$ (significant correlation)
$\hat{a}p < 0.1$ (marginally significant correlation)

CONCLUSIONS

Data analysis indicates some important trends that can guide future strategies in viticulture and winemaking:

The increase in average temperatures in recent years has favored the accumulation of anthocyanins, which indicates a possible intensification of the color of the wines produced.

Varieties with high acidity show greater stability over time, suggesting a high potential for aging.

Sugars and polyphenols are directly influenced by climatic conditions, which requires the adaptation of winemaking technologies to maintain aromatic and structural balance.

The regression between temperature and anthocyanins shows that in areas with warmer climates, varieties with a good adaptability can have a competitive advantage in the production of premium wines.

These trends suggest that climate change and variations in chemical composition need to be taken into account in cultivation and winemaking strategies to ensure consistent red wine quality.

Based on the observed trends and the relationships identified between the climatic variables and the chemical parameters of the grapes, a forecast can be made on the evolution of the oenological potential of the analyzed varieties:

Varieties with high sugar accumulation could become sweeter in the future, due to the

increase in average temperatures, which could require adjustments in winemaking technology to maintain the alcoholic balance.

Lower rainfall could lead to an increase in the concentration of polyphenols and anthocyanins, which would favor the production of more intense wines with a high aging capacity.

Varieties that are more sensitive to climate change may require technological adaptations, such as harvesting earlier or using cold maceration techniques to preserve phenolic compounds and acidity.

This forecast suggests that climate change will have a significant impact on the potential of red wines, and winemakers will need to adopt flexible strategies to maintain the quality and style of the wines produced.

Based on observed trends and climate change forecasts, the following recommendations can be made:

Adapting viticultural practices to optimize the accumulation of anthocyanins and polyphenols, given rising temperatures and variable rainfall.

Careful selection of varieties according to the wine region to maximize the potential of each type of wine produced.

Implementation of modern winemaking technologies, such as cold maceration and fermentation temperature control, to maintain the aromatic balance and stability of phenolic compounds.

Constant monitoring of climate change and adjustment of harvesting strategies to maintain optimal acidity and balanced sugar content.

In conclusion, this analysis provides essential information for winegrowers and oenologists, helping to develop superior quality wines, adapted to changing climatic conditions and international market requirements.

Comparative analysis of the chemical characteristics of red grape varieties revealed significant differences between them. These results can be useful for winemakers in selecting the right varieties according to the type of wine they want and for improving winemaking technology strategies.

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